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Smallmouth Bass Movement, Habitat Use and Electrofishing Susceptibility in Lower Lake Oahe, South Dakota

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Smallmouth Bass Movement, Habitat Use and Electrofishing Susceptibility in Lower Lake Oahe, South Dakota

By

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Completion Report

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Preface

Information summarized in this report was collected and analyzed from April of 1996 through December of 1998. Copies of this report and references to the data can be made with permission from the author or the director of the Division of Wildlife, South Dakota Department of Game, Fish and Parks, Foss Bldg. 523 E. Capitol, Pierre, SD 57501-3182.

I would like to acknowledge the following individuals from the South Dakota Department of Game, Fish and Parks that helped with data collection, processing, analysis, manuscript preparation and report editing; Kimberly Klinger, Darla Kusser, Dave Stout, Dennis Unkenholz, Cliff Stone, Jim Riis, Brian Blackwell, Tony Lief, Charlie Olson, Byron Ramlo, Chris Schumacher, Scott Wanetka, and Aimee Stoeser . Dave Willis and Rex Johnson, of South Dakota State University, assisted with manuscript review and Geographical Information System data manipulation techniques, respectively. A special note of thanks goes to Travis Tisher, who did the majority of the ArcView and ArcInfo work and who spent many hours alone in the darkness, listening to the beeps of sonic transmitters and waiting for the GPS unit to acquire new satellites.

The mention of manufacturers of ultrasonic telemetry and global positioning system equipment, and geographical information system and statistical analysis software, used in this study, does not imply that the South Dakota Department of Game, Fish and Parks endorses the products of these manufacturers.

Executive Summary

South Dakota Department of Game, Fish and Parks (SDGFP) successfully introduced smallmouth bass into various reaches of Lake Oahe, South Dakota from 1983 through 1989. Smallmouth bass are naturally reproducing in Lake Oahe and increasing in abundance, though angler use of the population remains relatively low. A standardized population survey, where biases in smallmouth bass population size structure are minimized, has not been established. It is generally believed that electrofishing survey samples under-represent actual smallmouth bass population size structure. In addition, under-utilization of the Lake Oahe smallmouth bass population by anglers most likely results from inadequate angler knowledge of large smallmouth bass movement, habitat use and activity patterns. Therefore, diel movements, habitat use and activity patterns of two smallmouth bass length groups (medium: 240-290 mm and large: ≥ 350 mm) were monitored in two habitat types (rip-rap and natural bay) in lower Lake Oahe, South Dakota, from May 1996 through October 1996. Seasonal movements and habitat use were monitored from May 1996 through October 1997. Information on smallmouth bass habitat use (bottom depth occupied and distance to shore) was used to determine the percent of nighttime smallmouth bass locations where fish were susceptible to electrofishing. Electrofishing susceptibility was then compared to electrofishing catch per unit effort (CPUE; No./h) and structural indices and the optimum period of the year to conduct electrofishing surveys, to maximize sample size while minimizing biases in structural indices, was identified. Smallmouth bass home range characteristics were also documented.

A total of 61 medium and large smallmouth bass were implanted with ultrasonic transmitters and tracked during the May 1996 to October 1997 period. Large smallmouth bass began moving shallower and closer to shore in late May in 1996 and late April in 1997, a few weeks before medium fish did, as surface water temperature increased above 5^{o}C. Medium smallmouth bass generally moved shallower and closer to shore in early June as water temperatures approached 10^{o}C.

Large smallmouth bass were generally located deeper and further from shore than medium bass. However, patterns among months for distance to shore, bottom depth and temperature occupied were similar for the two smallmouth bass length groups. Establishment of summer home ranges by large fish on long, shallow sloping main-lake points and flats resulted in the median distance to shore of large fish increasing greatly, while fish were still located relatively shallow (<5-m deep).

For all months during the June-October 1996 period, except June, monthly median hourly movement rates were greater for large smallmouth bass. Peaks in diel median hourly movement rates for large smallmouth bass occurred during the rise-day (period between sunrise and daytime periods) and at sunset, while peaks in diel median hourly movement rate for medium fish occurred at sunrise and sunset, for the May-October 1996 period.

Bottom depth occupied and distance to shore were significantly negatively correlated with temperature occupied for both length groups of smallmouth bass studied during July-September 1996, the period of summer thermal stratification in Lake Oahe. Surface light intensity was significantly correlated with occupied depth for both length groups of smallmouth bass studied during June and August, although, r_s values (Spearman's Rho) were low, ranging from 0.17 to 0.27.

Home range area and core area estimates for large smallmouth bass summer home ranges were larger than estimates for medium fish summer home ranges. Shapes of home ranges closely followed bottom contours and patterns in available substrate strongly matched bottom contours. Clay, gravel and cobble substrates were common in all smallmouth bass home ranges, when home ranges were not located on areas of rip-rap.

The electric field of the Smith-Root electrofishing boat used in this study was mapped using a voltage gradient probe and a voltage gradient of 0.1 V/cm was used as the boundary of the effective electrofishing range of the boat. Susceptibility to electrofishing was defined as the percentage of nighttime smallmouth bass locations within 10-m of shore and in < 2-m of water. Nighttime electrofishing CPUE for medium smallmouth bass, at the natural bay sampling site, was strongly correlated to susceptibility of medium fish to electrofishing (r_s=0.85, P<0.03). Medium smallmouth bass CPUE at the rip-rap sampling site initially followed the same pattern as electrofishing susceptibility (June-July 1996) but medium fish electrofishing CPUE and electrofishing susceptibility were not strongly correlated (r_s=-0.09, P>0.10) for the June-October 1996 period. Susceptibility of large smallmouth bass implanted with ultrasonic transmitters was

significantly correlated with electrofishing CPUE for both the rip-rap and natural bay electrofishing sites (r_s=0.80, P<0.03, and r_s=0.74, $P<0.05$, respectively). Only during the June-July (late June) and September-October sampling periods were electrofishing susceptibilities of medium and large smallmouth bass similar. Electrofishing surveys in lower Lake Oahe should be initiated when water temperatures reach 15 ^{o}C and conclude when water temperatures reach 20^{o}C, to maximize sample size and minimize bias in structural indices calculated.

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Introduction

South Dakota Department of Game, Fish and Parks (SDGFP) successfully introduced smallmouth bass *Micropterus dolomieu* into various reaches of Lake Oahe, South Dakota from 1983 through 1989. Smallmouth bass currently are naturally reproducing in Lake Oahe and increasing in abundance, although angler use remains relatively low (Johnson et al. 1998). Studies of smallmouth bass population survey strategies on Lakes Oahe and Sharpe have shown that smallmouth bass population structural indices are highly variable and may be related to basin slope, substrate composition, time of year and on-shore wind conditions prior to electrofishing (SDGFP unpublished data). It is generally believed that smallmouth bass electrofishing estimates of population size structure under-represent actual population size structure. Proportional stock density (PSD; Anderson 1980) and relative stock density of preferred-length fish (RSD-P; Anderson and Neuman 1996) values from angling samples and trap-net samples (Laarman and Ryckman 1982) are generally higher than for electrofishing samples, suggesting that electrofishing may be less efficient at sampling large (≥ 350 mm total length; TL) smallmouth bass (Green et al. 1986; Beamesderfer and Riemer 1988). If optimum times and conditions for conducting electrofishing surveys could be identified and/or appropriate correction factors for smallmouth bass size structure could be generated, the quality of the information gathered from electrofishing surveys could be maximized to better represent the at-large population.

Under-utilization of the Lake Oahe smallmouth bass population by anglers most likely results from inadequate angler knowledge of large smallmouth bass movement, habitat use and activity patterns. Making this information available to anglers may improve angler success when fishing for smallmouth bass and potentially generate more interest in the fishery.

In addition, determining if discrete stocks of smallmouth bass exist in Lake Oahe will enable SDGFP to determine the level at which the smallmouth bass population and angler use of this population should be assessed. For example, are smallmouth bass at Oahe Dam a distinct stock of fish from those in Spring Creek? Past studies have documented differences in individual growth rates of age-1 to age-3 fish and different angler harvest rates for smallmouth bass among sampling areas (Lott 1996) but information on movements of smallmouth bass is necessary to determine if distinct stocks exist and if applying regulations to distinct stocks is necessary.

Strategy 1.2 of the 1995 Lake Oahe Strategic Plan (SDGFP unpublished) called for fish population surveys to be conducted and improved on a regular basis. A standardized smallmouth bass population survey cannot be initiated until potential biases associated with smallmouth bass electrofishing are better understood. The results of this study may enable development and implementation of a standardized smallmouth bass population sampling survey for all South Dakota Missouri River reservoirs. A lack of information on smallmouth bass movement, habitat use, and activity patterns, and a general lack of interest in smallmouth bass by reservoir anglers, were identified as major issues in current Lake Oahe smallmouth bass management efforts (SDGFP, unpublished). Strategies SMB2 and SMB4 of the 1995 Lake Oahe Strategic Plan directly address these inadequacies in the Lake Oahe smallmouth bass program. This study was conducted to satisfy these strategies.

The objectives of this study were as follows:

1. Document seasonal movements and habitat use of two smallmouth bass length groups (240-290 mm and ≥ 350 mm) in two habitat types (rip-rap and natural bay) in lower Lake Oahe, from May 1996 through October 1997.

2. Document diel movement, habitat use and activity patterns of two smallmouth bass length groups (240-290 mm and ≥ 350 mm) in two habitat types (rip-rap and natural bay) in lower Lake Oahe, from May 1996 through October 1996.

3. Monitor seasonal trends in smallmouth bass electrofishing catch rates and size structure and relate biases in smallmouth bass electrofishing survey indices [size structure and catch per unit effort (CPUE)] to smallmouth bass electrofishing susceptibility, based on occupied depth and distance to shore.

4. Provide information on smallmouth bass seasonal movement, habitat use and activity patterns to anglers in an attempt to improve angler success and ultimately use of Lake Oahe smallmouth bass populations.

Electrofishing has been identified as the most effective standard survey method for capturing smallmouth bass, although it is generally believed that electrofishing underestimates actual population size structure (Green et al. 1986; Beamesderfer and Riemer 1988). Previous SDGFP sampling efforts have documented that indices of smallmouth bass abundance (CPUE) and size structure vary greatly among sampling dates, environmental conditions, such as degree of onshore wind prior to electrofishing, and basin slope.

Increased angler knowledge of smallmouth bass movements and habitat use, especially for large (≥ 350 mm) smallmouth bass, may result in increased angler success and satisfaction and thus better utilization of smallmouth bass populations in Lake Oahe and other South Dakota Missouri River reservoirs.

Knowledge of movement and habitat use effects on smallmouth bass population structural indices from electrofishing samples will improve knowledge of optimal times and conditions for sampling smallmouth bass. To adequately manage smallmouth bass populations in Lake Oahe it is important to have reliable estimates of smallmouth bass population structural indices and be able to monitor changes in these indices over time. Unreliable estimates of population size structure result in unreliable estimates of population age structure and mortality rates, and therefore, the proportion of mortality that is natural or angler induced cannot be accurately determined.

Study Area

Lake Oahe is a 150,000-ha, mainstem, Missouri River storage reservoir that was constructed to alleviate flooding, generate electric power, support water development projects and provide recreation. Lake Oahe is managed for coolwater and coldwater game fish species including walleye *Stizostedion vitreum* , northern pike *Esox lucius*, smallmouth bass, channel catfish *Ictalurus punctatus*, white bass *Morone chrysops*, rainbow trout *Oncorhyncus mykiss* and chinook salmon *Oncorhyncus tshawytscha*. Physical characteristics of Lake Oahe are listed in Table 1 while geographic locations mentioned in this report appear in Figure 1.

Table 1. Physical characteristics of Lake Oahe.

Oahe Dam Closed in:	1958	***Reservoir length:**	372 km
Elevation at full pool:	1617 msl	***Shoreline length:**	3620 km
***Surface area:**	150144 ha	**Drainage Area:**	630639 km^2
***Water volume:**	$2.9x10^{13}$ l	***Average Depth:**	18.3 m
***+Coldwater habitat:**	47755 ha	***Maximum Depth:**	62.5 m
Trophic Status:	oligotrophic/ mesotrophic	**MEI:#**	28.4
Shoreline Development Index:	26.4	**Storage Ratio:**	1.05

*Denotes values for water elevation at full pool.
+Denotes volume of water ≤15°C.
#MEI: Morphoedaphic index (Ryder 1965)

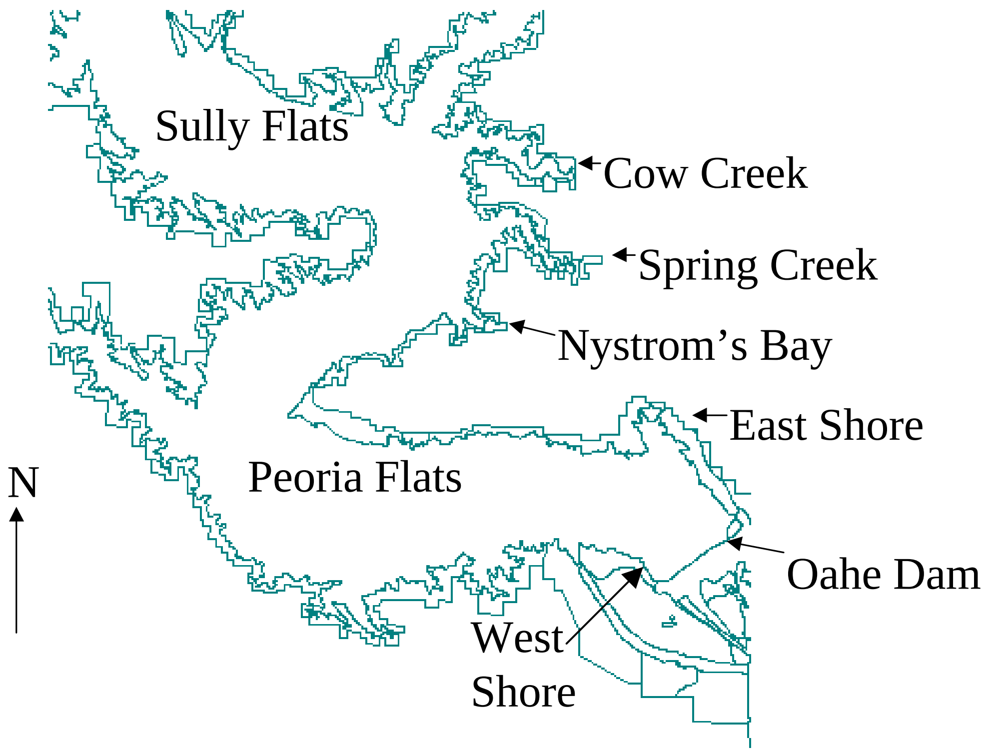

Figure 1. Lower Lake Oahe study area, including locations mentioned in this report.

Initial sampling areas included one rip-rap habitat area (face of Oahe Dam) and one natural-bay habitat area (Spring Creek; Figure 1). Spring Creek has a surface area of 191 ha (full pool). Substrates in Spring Creek are composed of sand, silt and gravel, with small patches of rock/rubble and boulder. In general, the shoreline slope of Spring Creek is more gradual than the slope of Oahe Dam, which is 3-4:1. Oahe Dam is approximately 3.6 km in length and has rip-rap, composed of large boulders, as the sole substrate. Rip-rap on Oahe Dam extends to a depth of approximately 20 m (full pool). The 1993 and 1994 Lake Oahe smallmouth bass population electrofishing surveys (SDGFP unpublished), and a 1994 smallmouth bass feeding ecology study (Lott 1996) documented higher electrofishing catch rates but lower smallmouth bass population size structure on the face of Oahe Dam than in natural bays.

Methods

Field Collection of Smallmouth Bass

Smallmouth bass for the habitat use and movement portion of this study were primarily collected during late May and early June of 1996 by a combination of pulsed-DC, nighttime electrofishing. All smallmouth bass implanted with transmitters were initially captured in Spring Creek or at Oahe Dam. Two distinct length groups of smallmouth bass were used in the habitat use and movement portion of this study. Smallmouth bass between 240 mm and 290 mm total length (TL) were classified as "medium" fish, while individuals ≥ 350 mm TL were classified as large fish. Smallmouth bass between 240 mm and 290 mm TL, in Lake Oahe, are generally not sexually mature, while bass ≥ 350 mm TL are all sexually mature. Smallmouth bass <240 mm TL were not included in the study because ultrasonic transmitters of the required battery life but small enough to be internally implanted in fish of this size were not available. Smallmouth bass between 290 mm and 350 mm TL were not included in the study because the state of maturity of these fish was unknown. Also, with a limited number of transmitters available for implantation, it was decided to maximize sample size in the two length groups studied, rather than study three length groups with fewer transmittered fish in each length group.

Surgical Implantation of Transmitters

During late May and early June 1996, 11 smallmouth bass from each length group, at each study site, were implanted with ultrasonic transmitters manufactured by Sonotronics (Tuscon, AZ). Sonic transmitters were used instead of radio transmitters because smallmouth bass are located at depths beyond the range of radio telemetry equipment at certain times of the year (Ridgway and Shuter 1996). Smallmouth bass implanted with transmitters were chosen so that transmitter weight was <2% of fish weight, to prevent the presence of a transmitter from influencing fish behavior or movement (Winter 1983). During the course of the study, when fish either expelled transmitters and they were recovered by staff or transmitters were recovered by anglers, additional smallmouth bass were implanted with transmitters. Medium smallmouth bass (240 to 290-mm length group) were implanted with transmitters with a 12-month life expectancy that were not temperature sensitive. Large smallmouth bass (≥350-mm length group) were implanted with transmitters with a 14-month life expectancy that were temperature sensitive. After weighing, smallmouth bass were placed ventral side up in a v-shaped, padded trough, with water over the gills, for surgical implantation of transmitters (Kraii et al. 1991). Surgical techniques closely followed those described by Summerfelt and Smith (1990). A 10% povidine-iodine antiseptic was applied to the area of the planned incision. Scales were removed from the incision area and an incision approximately 20-mm long was made just anterior of the anus, on the ventral side (Warden and Lorio 1975), just large enough to insert the transmitter. The linea alba and parietal peritoneum were cut using a scalpel and the opening was lengthened by cutting with the scalpel between the arms of a pair of forceps (Hart and Summerfelt 1975). Simple-interrupted sutures were used to close the incision after transmitter insertion into the peritoneal cavity (Summerfelt and Smith 1990). Attempts were made to sex fish implanted with transmitters by examining internal anatomy during surgery. All surgical instruments and transmitters were disinfected before each operation. Red dangler tags were externally attached to each transmittered fish. Dangler tags were labeled with an individual four-digit code number on one side of the tag and the words “release immediately” on the other side of the tag. Informational signs at lake access areas informed anglers and spear-fishermen about the presence of transmitters in smallmouth bass with bright red dangler tags attached to them. Smallmouth bass were then held in an aerated livewell until they regained equilibrium and were released near shore, near the location of capture. Fish were not held beyond equilibrium recovery because holding may cause additional stress and increases post-operative mortality (Hart and Summerfelt 1975). Smallmouth bass were allowed a 7-day post-surgery acclimation period before data was recorded on fish locations and movement. Tracking was conducted during the interim to practice tracking techniques and maintain contact with transmittered fish, although no data were recorded.

Tracking of Sonically-Tagged Smallmouth Bass

From May through October of 1996, six, 12-h tracking periods were scheduled each month, at each study site, using a stratified random schedule to select tracking dates and periods. Three tracking sessions were scheduled each month at each study site, for each tracking period. Tracking periods were defined as follows: AM – 12:00 A.M to 11:59 A.M.; PM – 12:00 P.M to 11:59 PM. Previous researchers have observed very little, if any, activity by smallmouth bass after dark (Emery 1973; Peterson and Myhr 1976; Reynolds and Casterlin 1976; MacLean et al. 1982; Gerber and Haynes 1988). However, nighttime tracking was included to establish beginning or ending locations for determination of smallmouth bass activity during sunrise and sunset and to determine smallmouth bass susceptibility to nighttime electrofishing. From November through April, during periods of ice cover, three randomly selected, mid-day tracking periods were scheduled at each study area each month. During open water periods, three additional tracking periods were conducted each month outside of the study areas in attempts to locate study fish that traveled outside of the study area. When severe weather was encountered on a scheduled tracking day, tracking was postponed until the day after the severe weather had passed.

Each tracking period began at a randomly selected boat ramp and each study area had two boat ramps. At Oahe Dam, when launching at either ramp, the tracking boat proceeded in a direction toward the dam. Oahe Dam tracking sessions included the lower portion of the reservoir up to and including Peoria Flats (Figure 1). At Spring Creek, the direction of travel from the launch ramp was counter-clockwise from the Spring Creek ramp and clockwise from the Oahe Lodge ramp. Spring Creek tracking sessions included the area of the reservoir upstream of Peoria Flats to Sully Flats (Figure 1).

At the beginning or end of each tracking period, a temperature profile and sechhi depth reading were completed. During each tracking period, as many laps of the study area as possible were made. Fish were located using a directional hydrophone with equal signal strength, in all directions, indicating a fish was directly below the hydrophone. Individual fish locations and time of locations were recorded using a Trimble (Sunnyvale, CA) Geoexplorer Global Positioning System (GPS). At least six GPS positions were recorded at each fish location. The position dilution of precision (PDOP) mask on the Trimble Geoexplorer unit was set at six, to ensure GPS positions of fish locations were only recorded when a high degree of accuracy was possible. At each fish location, water depth and presence or absence of cover were determined from a liquid crystal graph and a paper graph recorder. If cover was present, every attempt was made to identify the type of cover. Cover was defined as any physical, natural or man-made item on the lake bottom (structure). Structure was defined as the topographic contours of the bottom, on which cover was located. Surface light intensity was measured using a light meter. Nearest distance to shore was estimated by overlaying smallmouth bass locations onto Geographical Information System (GIS) maps of the reservoir. Barometric pressure data for tracking periods were obtained from the National Weather Service office at the Pierre, SD airport. After each tracking session, locations of study fish were downloaded from the Geoexplorer unit into a personal computer and differentially corrected.

Only seasonal habitat use and movement patterns were monitored in 1997. Therefore, all tracking periods conducted from April through October of 1997 occurred during daylight hours.

Home Range Habitat Sampling

During the summer of 1997, habitat (depth, substrate and cover) of smallmouth bass home ranges established during 1996 was mapped. Home range locations were overlain with GIS maps of Lake Oahe to aid in location of home range areas when on the water. For each home range mapped, parallel transects were established using floating ropes and floats attached to anchors. Depth and substrate composition were determined at a number of locations along each transect and at each location a GPS position was recorded. Substrate classifications used when mapping home range substrate composition closely followed those used by Hubert and Lackey (1980) and included silt-clay, sand, gravel, rubble, boulder and bedrock.

Cover within each home range was mapped by snorkeling. Snorkelers thoroughly covered the area of each home range and placed a marker buoy at the location of each item of cover. Personnel in the boat then recorded the location of the cover item using the GPS recorder and recorded the type of cover present. Liquid crystal and paper graph recorders were also used to help locate cover in water too deep for visual inspection of the bottom by snorkelers near the surface. Once deeper cover was located, snorkelers were usually able to dive to the bottom and visually identify the cover present.

Coverages of home-range boundaries, water depth, bottom substrate and cover were overlaid onto reservoir maps to identify smallmouth bass habitat use patterns within home ranges.

Shoreline Mapping

The shorelines of Oahe Dam and Spring Creek were mapped during 1997 by walking the shoreline with the Trimble GPS unit over the range of water elevations encountered during the study. Generated files of shoreline position were then downloaded, differentially corrected and used to determine distance to shore of smallmouth bass locations.

Smallmouth Bass Electrofishing Surveys

Smallmouth bass at Oahe Dam and Spring Creek were collected by nighttime electrofishing with pulsed-DC current at bi-weekly intervals from May through October 1996 at each sampling area. Locations of electrofishing “runs” were standardized (same place each sampling time) for the duration of the study. Electrofishing was done using a 5.5-m Smith-Root electrofishing boat equipped with a 5,000-watt generator and paired Wisconsin ring electrodes. Six, 15-minute electrofishing runs were conducted at each sampling area, each month. All smallmouth bass captured on each electrofishing run were examined for external dangler tags, measured (TL, mm) and released.

Data Processing and Analysis

Percent of smallmouth bass locations where cover was being used was determined for medium and large fish, for the April-October 1996 period. The categories of rip-rap, rock, flooded trees and brush, and submerged aquatic macrophytes, were used to further classify cover use by fish.

Distance traveled between successive fish locations was determined using latitude and longitude location references to calculate the lengths of the two sides of a right-angle triangle. The length of the hypotenuse of the triangle was then the minimum distance traveled between successive observations. Hourly movement rates were determined by dividing distance between successive observations by the associated time interval. For analysis of diel activity patterns, in terms of hourly movement rate, pairs of fish observations were assigned to a diel period of the day as follows: sunrise - 2-h before and after sunrise, day – 2-h after sunrise to 2-h before sunset, sunset – 2-h before sunset to 2-h after sunset, night – 2-h after sunset to 2-h before. Pairs of fish observations that overlapped two diel periods were classified accordingly (i.e. night-sunrise, etc).

Smallmouth bass locations were overlaid onto Lake Oahe maps in ArcView 3.0 (Environmental Systems Research Institute, Inc. 1996) to generate maps of monthly and seasonal (spawning, summer and fall/over-winter) fish locations, by fish size. Distinctions between seasonal periods were based on field observations of fish locations and behavior patterns. Distances of smallmouth bass to shore were also determined using ArcView GIS 3.0.

Home range habitat maps were generated in ArcView 3.0 (Environmental Systems Research Institute, Inc. 1996). For this study, a home range was defined as an area that a smallmouth bass occupied for an extended period of time, usually during a particular season of the year. Home ranges were generated using the adaptive kernel method (Worton 1989) and the CALHOME software package (Kie et al. 1994). In the CALHOME program, the default band width for each home range generated was reduced by 50% and the grid-cell size was set at 50 m. Home range size was set as the area encompassing 90% of fish locations and core areas were set as the area encompassing 50% of fish locations. Calculated home ranges were imported from CALHOME into PC ArcInfo (Environmental Systems Research Institute, Inc. 1994) and then used in ArcView 3.0 (Environmental Systems Research Institute, Inc. 1996) for further estimation of home range size. Because estimated home ranges often include areas of land when applied to fish species that relate strongly to shallow water contours (Ridgway and Shuter 1996) , the area of the home range overlapping land was subtracted, in ArcView 3.0, when calculating home range size.

Home range habitat maps were generated by overlapping depth and bottom substrate transects with home range boundary maps and then manually drawing in contours in ArcView 3.0. To determine percent composition for each substrate type present in a home range or core area, outlines of polygons for each substrate type were manually traced, then the area of each substrate type was divided by either home range area or core area.

Catch per unit effort (CPUE, No./h) for each length group of smallmouth bass studied (medium or large), and PSD and RSD-P values were generated for electrofishing samples. The electric field of the Smith-Root electrofishing boat used in this study was mapped using a voltage gradient probe and a voltage gradient of 0.1 V/cm was used as the boundary of effective electrofishing range (Kolz et al. 1995). A smallmouth bass implanted with a sonic transmitter was considered susceptible to electrofishing if it was located within 10 m of shore and ≤ 2-m deep, between sunset and sunrise. Nighttime location information was split into 20-d intervals to correspond with electrofishing samples, for comparison of size-specific susceptibility and electrofishing CPUE.

Statistical Analyses

Data were statistically analyzed using SYSTAT (SYSTAT 1998) and SAS (SAS Institute 1985). Data were tested for normality and homogeneity of variances prior to any statistical tests. Variables such as hourly movement rate, depth, temperature and distance to shore, did not meet the assumptions of normality or equal variances and were therefore tested for differences among fish size and month using the Kruskal-Wallis test (Conover 1980). When differences existed among treatment groups, multiple comparison tests were used to determine where differences existed (Conover 1980). Medians were determined for depth, temperature, distance to shore and hourly movement rate and approximate 95% confidence intervals calculated (Daniel 1990) to provide an indication of variance about median values. Chi-Square analysis was used to test for differences in percent cover use between length groups and among months.

Smallmouth bass electrofishing CPUE was analyzed for effects of month and length group using analysis of variance (ANOVA). Catch data were not normally distributed and were $\log_{10}(n+1)$ transformed to better meet the assumption of normality prior to running the ANOVA procedure. The Least Square Means procedure (SAS 1985) was used to determine where differences existed. Proportional stock density and RSD-P values from electrofishing samples were compared between sampling sites, sampling periods and months using Chi Square tests. Spearman's rank correlations (Conover 1980) were calculated to determine the strength of correlations between environmental variables (surface light intensity and barometric pressure) and characteristics of smallmouth bass habitat use and movement (hourly movement rate, depth, temperature, distance from shore). Spearman's rank correlation was also used to test for correlations between electrofishing susceptibility and electrofishing CPUE. An alpha level of 0.05 was established, *a priori*, for all statistical tests, for acceptance or rejection of null hypotheses.

Results and Discussion

When transmittered fish were initially located, no changes in movement patterns were observed when the tracking boat was positioned over a fish to record its location. Stasko and Pincock (1977) noted no effect of the tracking boat on fish behavior. Although many of the occupied depths recorded during my study were <2-m deep, we are confident that the presence of the tracking boat did not spook smallmouth bass implanted with ultrasonic transmitters and affect fish location. In a study using ultrasonic transmitters to determine smallmouth bass locations and scuba diving to index smallmouth bass population characteristics, in Green Lake, Maine, smallmouth bass implanted with ultrasonic transmitters were never more than 2-m above the lake bottom (Cole 1994). Therefore, depths of water occupied by smallmouth bass are likely similar to actual depth occupied

Monthly Location Patterns

Smallmouth bass of both length groups, initially implanted with transmitters, were captured at the west and east corners of Oahe Dam and along the north shore of Spring Creek, from May 8 through June 5, 1996 (Figure 2). During June 1996, large smallmouth bass distributed from initial capture locations to suitable spawning areas throughout Spring Creek and along the east/north shore of the reservoir from Oahe Dam to Peoria Flats (Figure 3). Patterns in smallmouth bass movement from initial release locations suggest that they closely follow shoreline contours. Extensive use of shoreline contours by smallmouth bass was also documented by Peterson and Myhr (1976) and Robbins and MacCrimmon (1977). Hubert and Lackey (1980) determined that bottom relief was the primary variable governing smallmouth bass movement patterns in Pickwick Reservoir, Tennessee. A few large smallmouth bass initially captured at Oahe Dam remained at the dam during June and July, 1996. Medium fish generally remained in the area of initial capture during June and July 1996 (Figures 3 and 4), although a few fish initially captured at Oahe Dam moved to submerged islands near East Shore or to main-lake points on the south shore of the reservoir (Figure 4). Large fish generally took up residence between Spring Creek and Nystrom's Bay or at Peoria Flats, during July 1996. August 1996 fish locations were similar to July locations, although large fish were located deeper and further from shore than in July 1996 (Tables 2 and 3; Figure 5). In general, locations occupied during September 1996 for both length groups of smallmouth bass were deeper and further from shore than in August, although fish remained in the same general areas of the reservoir (Figure 6). During October 1996, large fish generally returned to steep drop-offs near or within Spring Creek or to Oahe Dam, leaving Peoria Flats and main-lake points, as water temperatures decreased below 15°C (Figure 7). Although maps of fish locations are not presented for 1997 data, patterns in fish locations, bottom depth, distance to shore and temperature occupied for 1997 were similar to those observed during 1996.

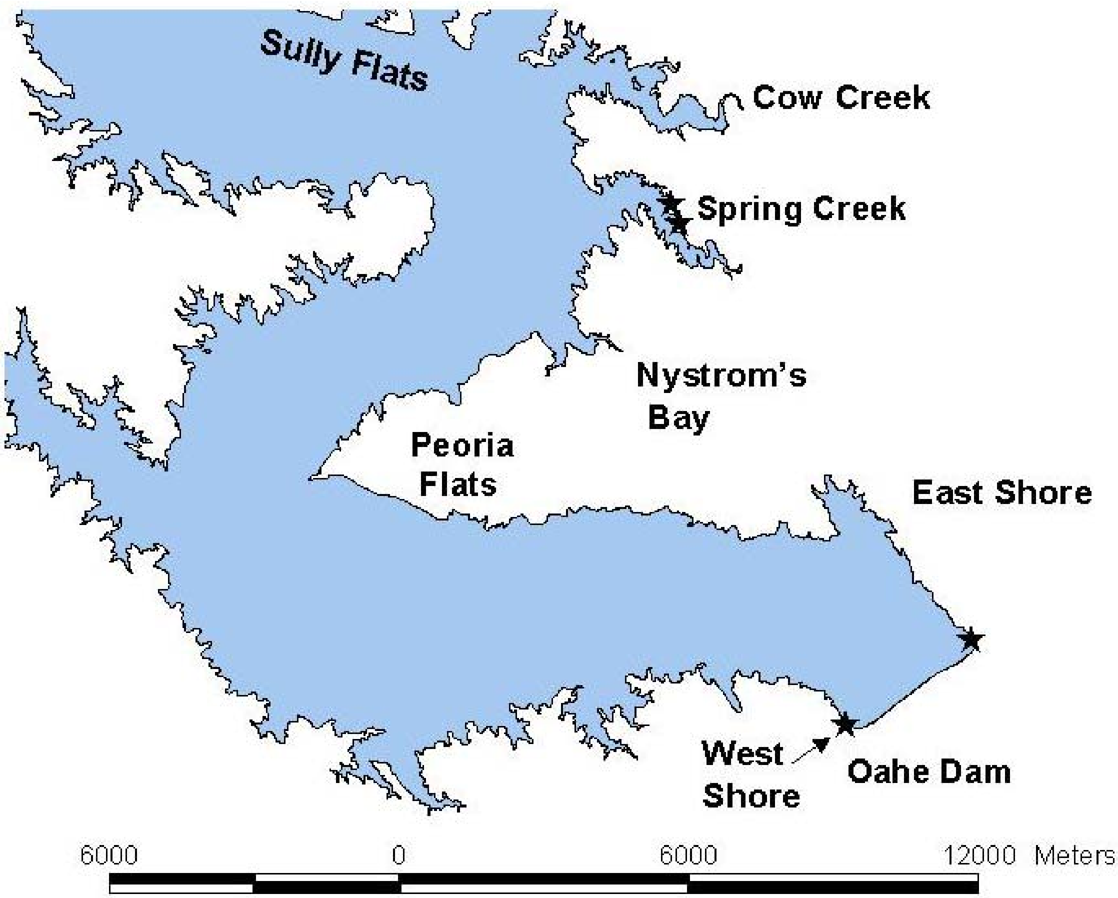

Figure 2. Initial release locations (indicated by stars) of smallmouth bass implanted with ultrasonic transmitters during late May and early June 1996, in lower Lake Oahe, South Dakota.

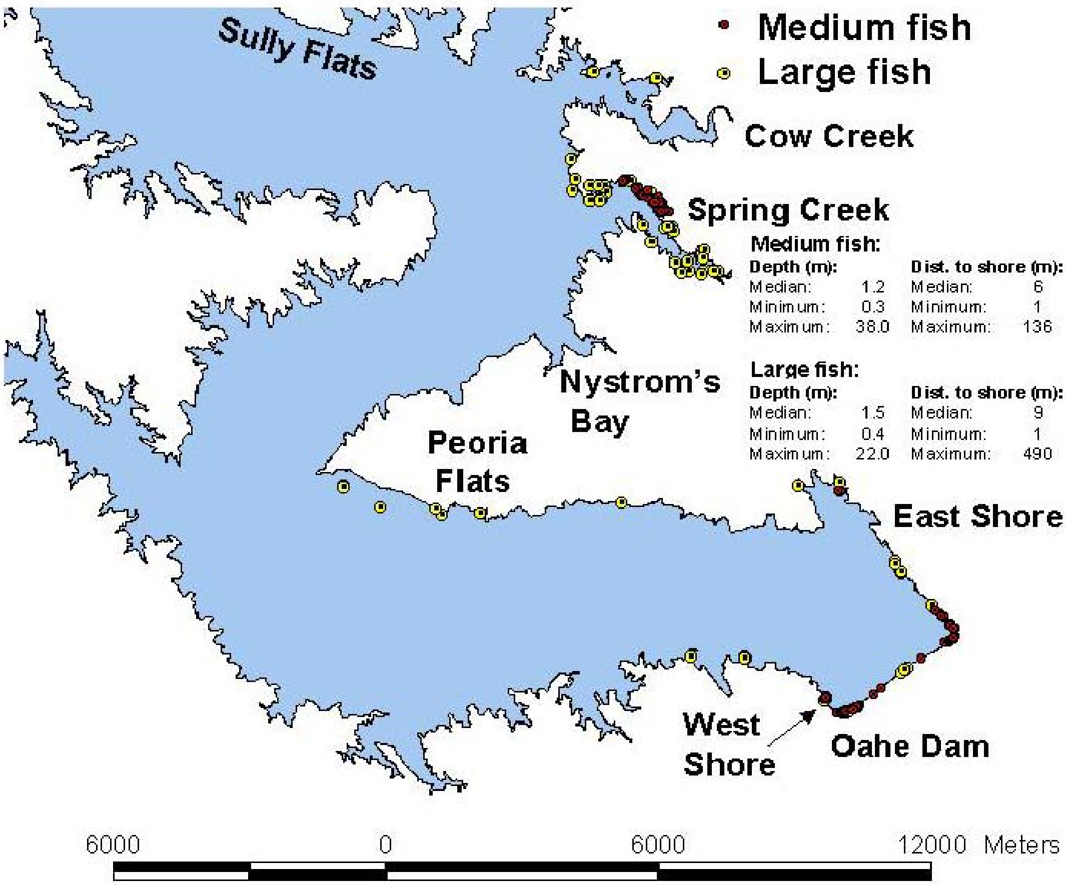

Figure 3. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, in lower Lake Oahe SD, during June 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

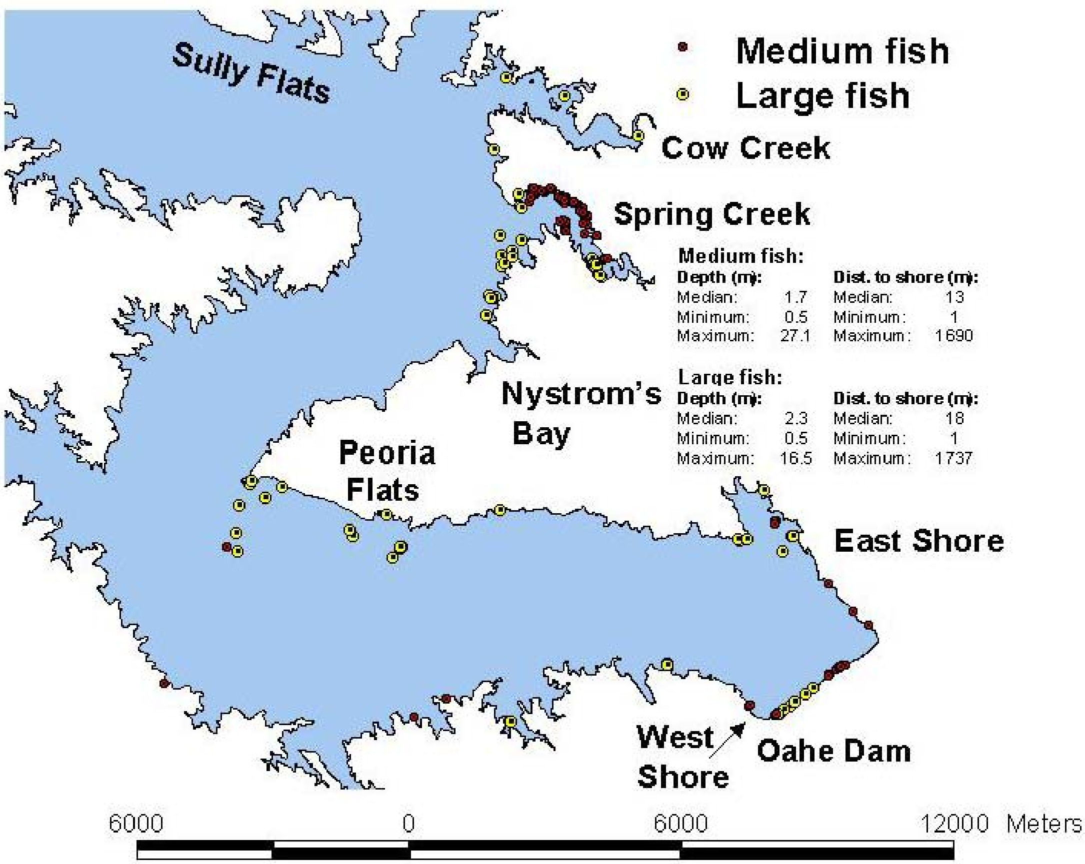

Figure 4. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, in lower Lake Oahe SD, during July 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

Table 2. Median distance to shore (m), by month, and approximate 95% confidence intervals, for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, on lower Lake Oahe, South Dakota, from May 1996 through October 1997. N is the number of observations for fish of the specified sizes.

Month	**Fish size**	**N**	**Median distance to shore (m)**	**95% confidence limit**	
				lower limit (m)	**upper limit (m)**
May 96	large	27	24.8	19.8	32.6
	medium	0	---	---	---
	combined	27	24.8	19.8	32.6
June 96	large	98	9.2	7.3	11.9
	medium	134	5.8	5.0	6.6
	combined	232	7.0	6.4	8.8
July 96	large	77	18.2	12.2	48.2
	medium	131	13.2	11.3	14.3
	combined	208	13.8	13.8	15.6
August 96	large	131	36.9	31.5	45.7
	medium	185	11.8	10.6	12.7
	combined	316	17.6	15.8	20.1
September 96	large	141	58.5	52.3	80.4
	medium	141	21.7	18.8	22.5
	combined	282	30.5	24.3	39.7
October 96	large	57	75.3	54.8	104.2
	medium	49	37.1	21.1	56.7
	combined	106	55.2	37.1	94.2
December 96	large	3	86.4	---	---
	medium	4	53.1	---	---
	combined	7	57.3	42.6	94.7
January 97	large	4	154.0	---	---
	medium	2	107.5	---	---
	combined	6	132.7	77.7	246.4
February 97	large	3	71.5	---	---
	medium	1	83.9	---	---
	combined	4	77.7	---	---
April 97	large	8	58.2	11.9	282.0
	medium	4	44.6	----	----
	combined	12	55.3	27.5	118.6
May 97	large	20	29.0	8.8	78.2
	medium	18	40.2	30.1	108.4
	combined	38	39.4	17.9	54.7
June 97	large	25	23.8	6.7	82.9
	medium	16	23.0	11.2	33.0
	combined	41	23.3	9.9	52.8

Table 2 continued.

Month	Fish size	N	Median distance to shore (m)	95% confidence limit	
				lower limit (m)	upper limit (m)
July 97	large	15	35.0	16.8	63.6
	medium	10	26.0	11.2	48.7
	combined	25	26.5	23.0	44.1
August 97	large	5	33.1	----	----
	medium	3	12.0	----	----
	combined	8	24.3	5.8	73.6
September 97	large	17	29.0	11.4	82.7
	medium	3	16.3	----	----
	combined	20	28.5	16.3	76.3
October 97	large	5	31.7	----	----
	medium	1	13.3	----	----
	combined	6	22.5	5.3	146.7

Table 3. Median bottom depth (m), by month, at smallmouth bass locations and approximate 95% confidence intervals, for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, on lower Lake Oahe, South Dakota from May 1996 through October 1997. N is the number of observations for fish of the specified sizes.

Month	Fish size	N	Median bottom depth (m)	95% confidence limit	
				lower limit (m)	upper limit (m)
May 96	large	30	2.3	1.8	3.0
	medium	0	---	---	---
	combined	30	2.3	1.8	3.0
June 96	large	99	1.5	1.4	1.8
	medium	160	1.2	1.1	1.3
	combined	259	1.3	1.2	1.4
July 96	large	81	2.3	2.1	3.5
	medium	131	1.7	1.5	1.8
	combined	212	1.8	1.6	2.1
August 96	large	139	3.1	2.7	3.4
	medium	189	1.6	1.4	1.7
	combined	328	2.0	1.8	2.1
September 96	large	154	4.9	4.3	5.5
	medium	168	3.8	3.5	4.2
	combined	322	4.3	3.8	4.9
October 96	large	60	9.0	7.6	12.9
	medium	61	8.0	5.6	10.1
	combined	121	8.5	6.6	11.1

Table 3 continued.

Month	Fish size	N	Median bottom depth (m)	95% confidence limit	
				lower limit (m)	upper limit (m)
December 96	large	3	20.5	---	---
	medium	4	17.0	---	---
	combined	7	17.4	9.6	22.5
January 97	large	4	14.6	---	---
	medium	2	15.4	---	---
	combined	6	14.6	7.0	18.9
February 97	large	3	17.7	---	---
	medium	1	21.6	---	---
	combined	4	19.7	16.7	33.3
April 97	large	8	15.4	2.7	22.3
	medium	4	9.8	----	----
	combined	12	12.1	2.7	22.3
May 97	large	22	3.1	1.6	11.9
	medium	25	13.6	9.8	15.3
	combined	47	10.1	6.7	14.0
June 97	large	26	2.7	1.4	15.1
	medium	17	2.9	1.6	12.9
	combined	43	2.9	1.9	12.5
July 97	large	19	4.0	2.1	5.6
	medium	13	3.0	1.7	9.9
	combined	32	3.6	2.5	4.7
August 97	large	5	4.6	----	----
	medium	3	3.7	----	----
	combined	8	4.6	2.0	12.5
September 97	large	18	4.4	3.3	7.5
	medium	3	2.8	----	----
	combined	21	4.3	2.9	7.5
October 97	large	5	4.1	----	----
	medium	1	2.8	----	----
	combined	6	3.6	1.8	5.6

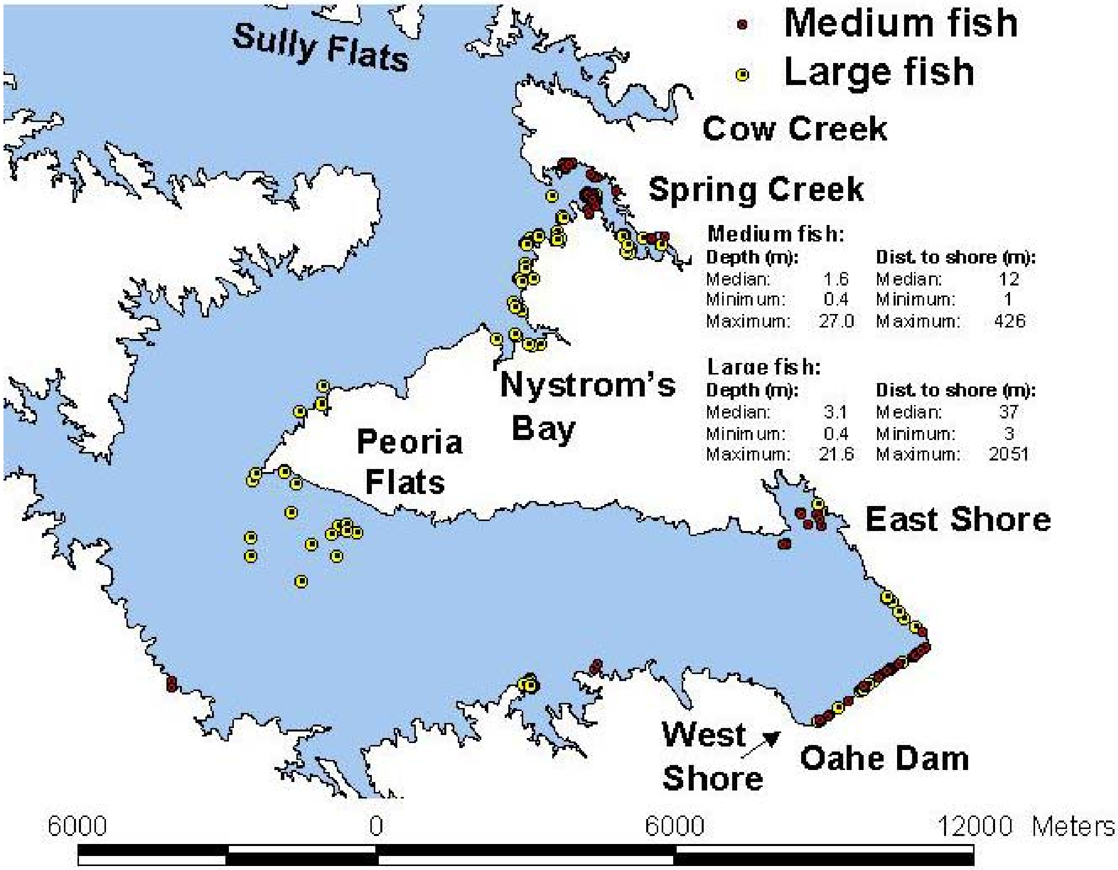

Figure 5. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, in lower Lake Oahe SD, during August 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

Distance to shore, bottom depth occupied and temperature occupied differed significantly among months during the May 1996 – October 1997 period, and between smallmouth bass length groups (P<0.01 in all cases). Large smallmouth bass were generally located deeper and further from shore than medium bass (Tables 2 and 3). However, 95% confidence intervals about median values for bottom depth occupied, distance to shore and temperature occupied often overlapped between months and length groups within a month. Patterns in distance to shore, bottom depth and temperature occupied, among months, were similar for the two length groups of smallmouth bass implanted with transmitters (Tables 2-4; Figures 8 and 9). Large smallmouth bass began moving shallower and closer to shore in late May in 1996 and late April in 1997, a few weeks before medium fish did, as surface water temperature increased above 5^{o}C (Figure 8). Medium smallmouth bass generally moved shallower and closer to shore in early June as water temperatures approached 10^{o}C (Tables 2-4; Figures 8 and 9). Shuter and Ridgway (1991) also noted the movement of large smallmouth bass into shallower water in the spring before smaller males moved shallow and suggested that this behavior was related to the establishment of nest sites by larger males. Although not analyzed as part of my study, female smallmouth bass were often deeper and further from shore than male bass during the pre-spawn and spawning-and-rearing periods (Cole 1994). During 1996, median values for smallmouth bass bottom depth and distance to shore, for both length groups of smallmouth bass, were lowest during the June spawning season (Tables 2 and 3). After June 1996, fish of both length groups moved to deeper water and were further from shore, with bottom depth occupied and distance to shore increasing through the December-1996-to-February-1997 period (Tables 2 and 3; Figure 9).

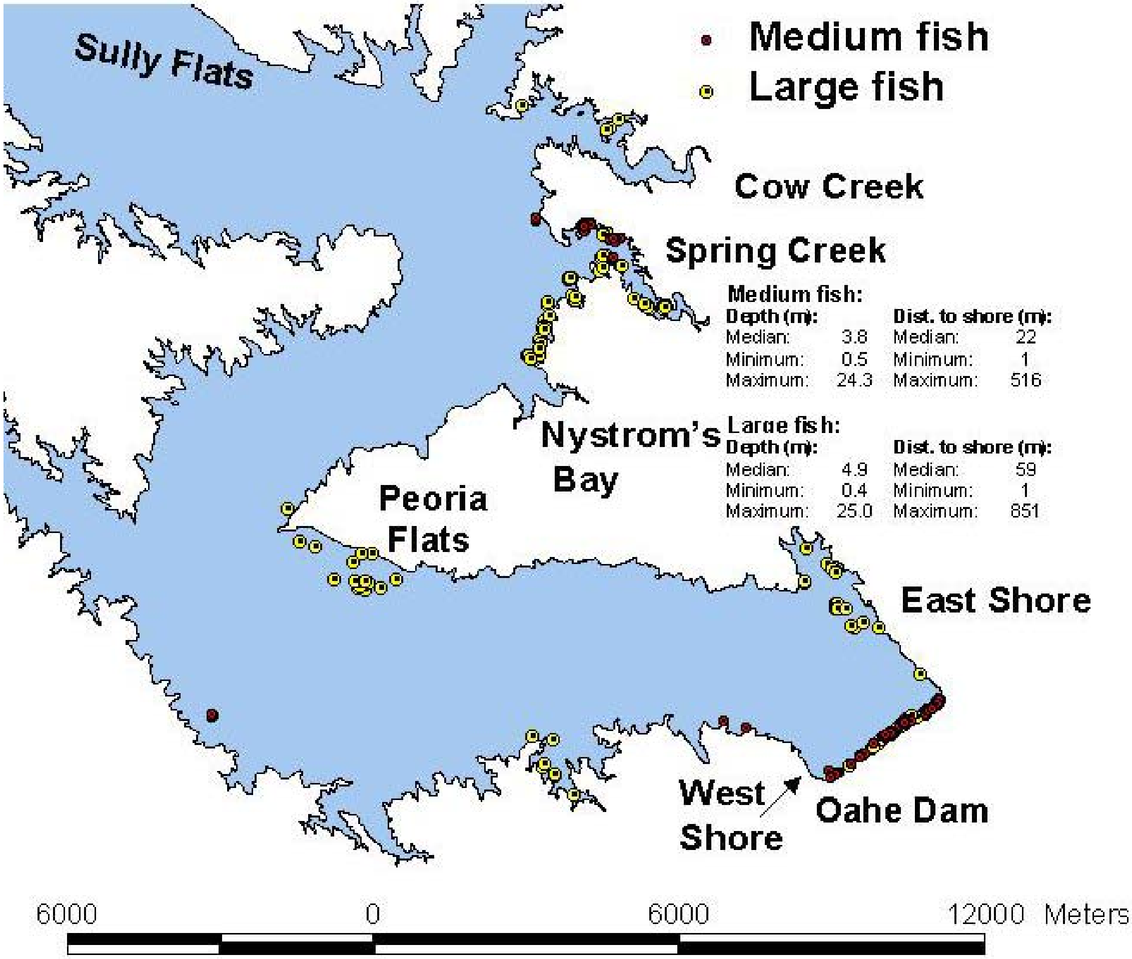

Figure 6. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, in lower Lake Oahe SD, during September 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

In 1997, the pattern of increasing bottom depth and distance to shore after June was not as evident and tracking ended before smallmouth bass moved to over-wintering areas (Tables 2 and 3; Figure 9). Low sample sizes for medium fish for April-September 1997 and large fish for August and September 1997 (Tables 2-4) are due to the expiration of transmitter batteries and the fact that only seasonal habitat use and movement patterns were monitored in 1997. All tracking periods conducted from April through October of 1997 were during daylight hours and the goal of each tracking period was to locate each smallmouth bass once per week.

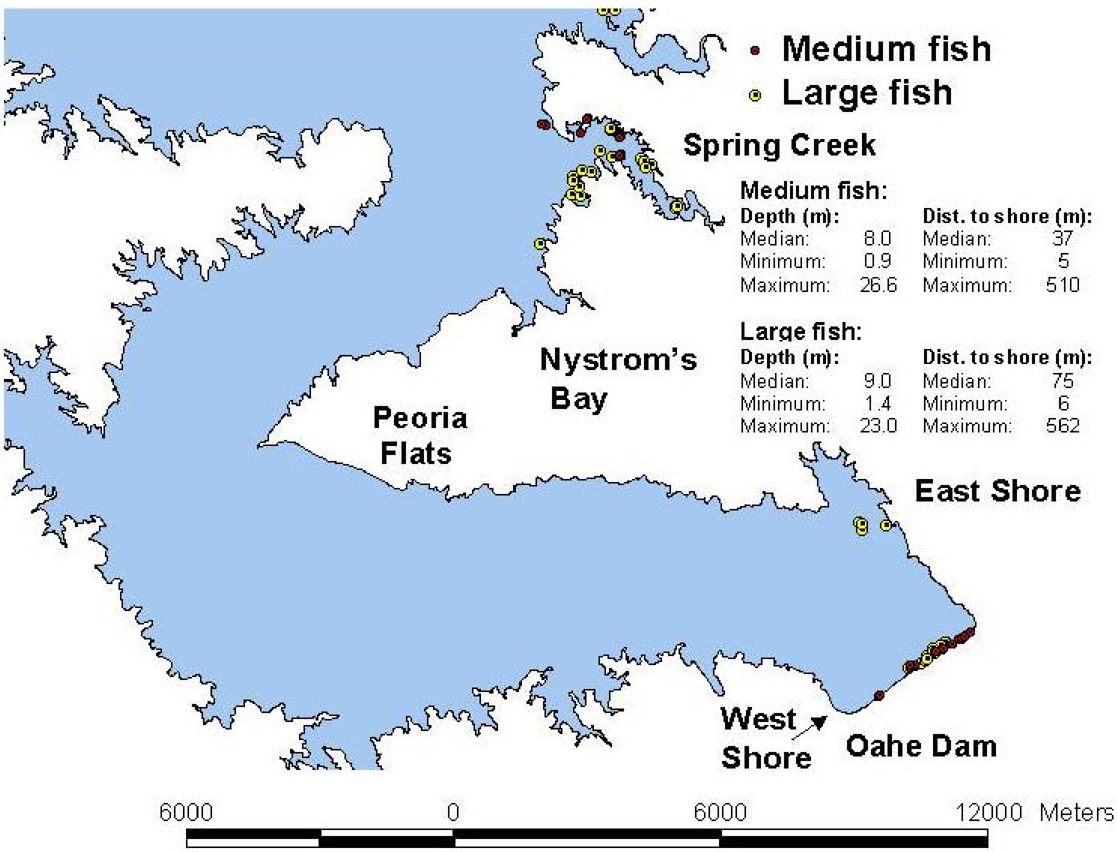

Figure 7. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥350mm) smallmouth bass implanted with ultrasonic transmitters, in lower Lake Oahe SD, during October 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

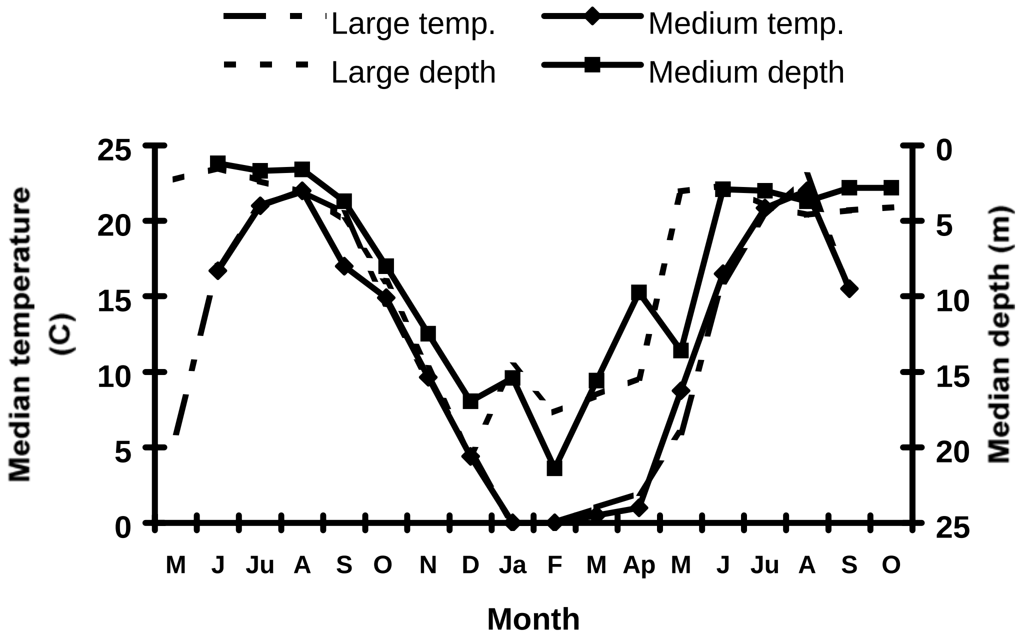

Figure 8. Median bottom depth and water temperature (temp.), of smallmouth bass locations, for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters and monitored from May 1996 through October 1997.

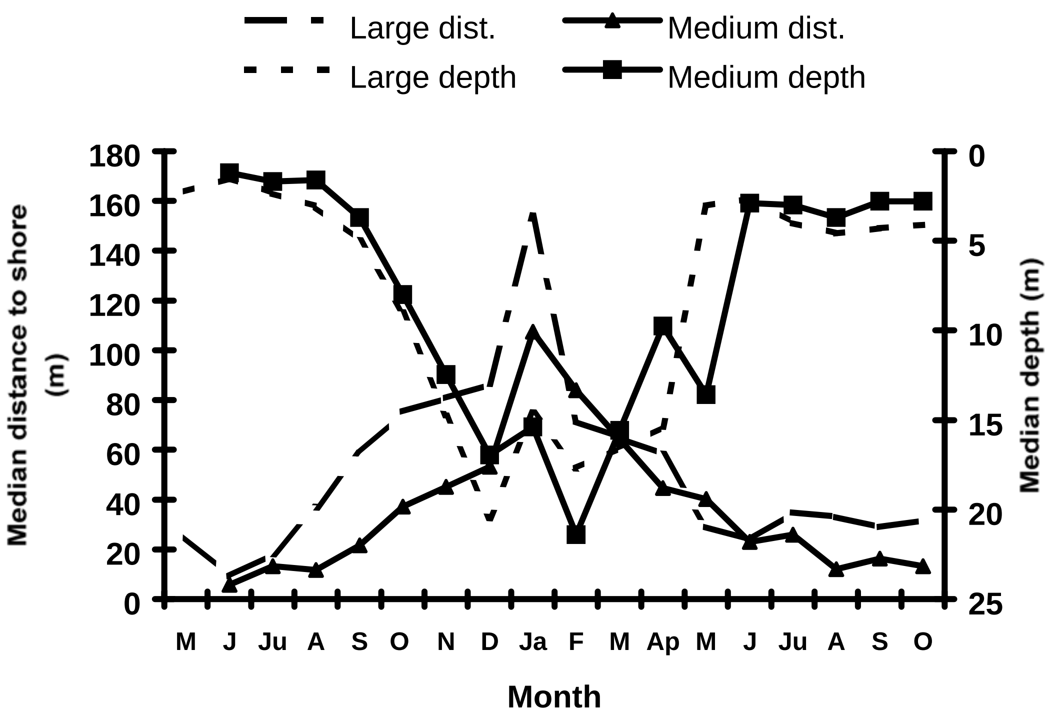

Figure 9. Median bottom depth and distance (dist.) to shore, of smallmouth bass locations, for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters and monitored from May 1996 through October 1997.

Table 4. Median calculated temperature at lake bottom (^oC), at smallmouth bass locations and approximate 95% confidence intervals, for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters on lower Lake Oahe, South Dakota from May 1996 through September 1997. N is the number of observations for fish of the specified sizes.

Month	**Fish size**	**N**	**Median calculated temperature (^{o}C)**	**95% confidence limit**	
				lower limit (m)	**upper limit (m)**
May 96	large	29	6.0	6.0	6.5
	medium	0	---	---	---
	combined	29	6.0	6.0	7.0
June 96	large	6	17.0	16.0	17.5
	medium	153	16.7	15.4	17.0
	combined	249	16.8	16.0	17.1
July 96	large	81	21.0	21.0	21.5
	medium	130	21.5	21.0	22.0
	combined	21	21.5	21.0	21.5
August 96	large	139	22.0	22.0	22.5
	medium	185	22.0	22.0	22.3
	combined	324	22.0	22.0	22.5
September 96	large	154	20.8	17.0	21.0
	medium	148	21.0	17.0	21.0
	combined	302	21.0	17.0	21.0
October 96	large	60	14.5	12.0	15.0
	medium	60	14.9	13.4	15.0
	combined	120	14.8	14.0	15.0
December 96	large	3	4.6	---	---
	medium	4	4.4	---	---
	combined	7	4.6	4.3	4.6
January 97	large	4	0.0	---	---
	medium	2	0.0	---	---
	combined	6	0.0	0.0	0.0
February 97	large	3	0.0	---	---
	medium	1	0.0	---	---
	combined	4	0.0	0.0	0.0
April 97	large	8	2.0	1.0	4.5
	medium	2	1.0	----	----
	combined	10	1.5	1.0	6.0
May 97	large	21	6.0	4.5	6.5
	medium	0	----	----	----
	combined	21	6.0	4.5	7.0

Table 4 continued.

Month	**Fish size**	**N**	**Median calculated temperature (^oC)**	**95% confidence limit**	
				lower limit (m)	**upper limit (m)**
June 97	large	26	16.0	8.5	18.0
	medium	6	16.5	----	----
	combined	32	16.0	9.5	18.0
July 97	large	18	20.3	19.0	21.5
	medium	8	22.6	20.4	23.0
	combined	26	21.0	20.0	22.8
August 97	large	5	23.0	----	----
	medium	3	22.0	----	----
	combined	8	22.5	21.0	23.0
September 97	large	7	15.5	----	----
	medium	3	15.5	----	----
	combined	10	15.5	15.5	21.0

Seasonal Location Patterns

Smallmouth bass habitat use in 1996 can be delineated into four distinct seasonal periods. These periods are the pre-spawn (prior to June 20), spawning-and-rearing (June 20 to July 15), summer (July 15 to September 30) and fall-and-over-winter (October 1 to March 31 1997) periods. The pre-spawn period was considered the period of time after smallmouth bass moved shallow in the spring and distributed from over-wintering areas to spawning areas. Surface water temperatures above 15^oC coincided with the beginning of the spawning-and-rearing period (Figure 10), during which smallmouth bass of both length groups were located in shallow water and near shore. Cole (1994) also noted that the beginning of the spawning period coincided with water temperatures of approximately 15 ^oC. Median bottom depths of smallmouth bass locations during the spawning-and-rearing period were 1.5 m and 2.1 m, for medium and large fish, respectively, while median distances to shore were 8 m and 12 m for medium and large fish, respectively (Figure 10). These values were not significantly different between length groups studied. Cole (1994) also found no significant difference in depth use among different sizes of smallmouth bass during the spawning and nesting period in Green Lake, Maine.

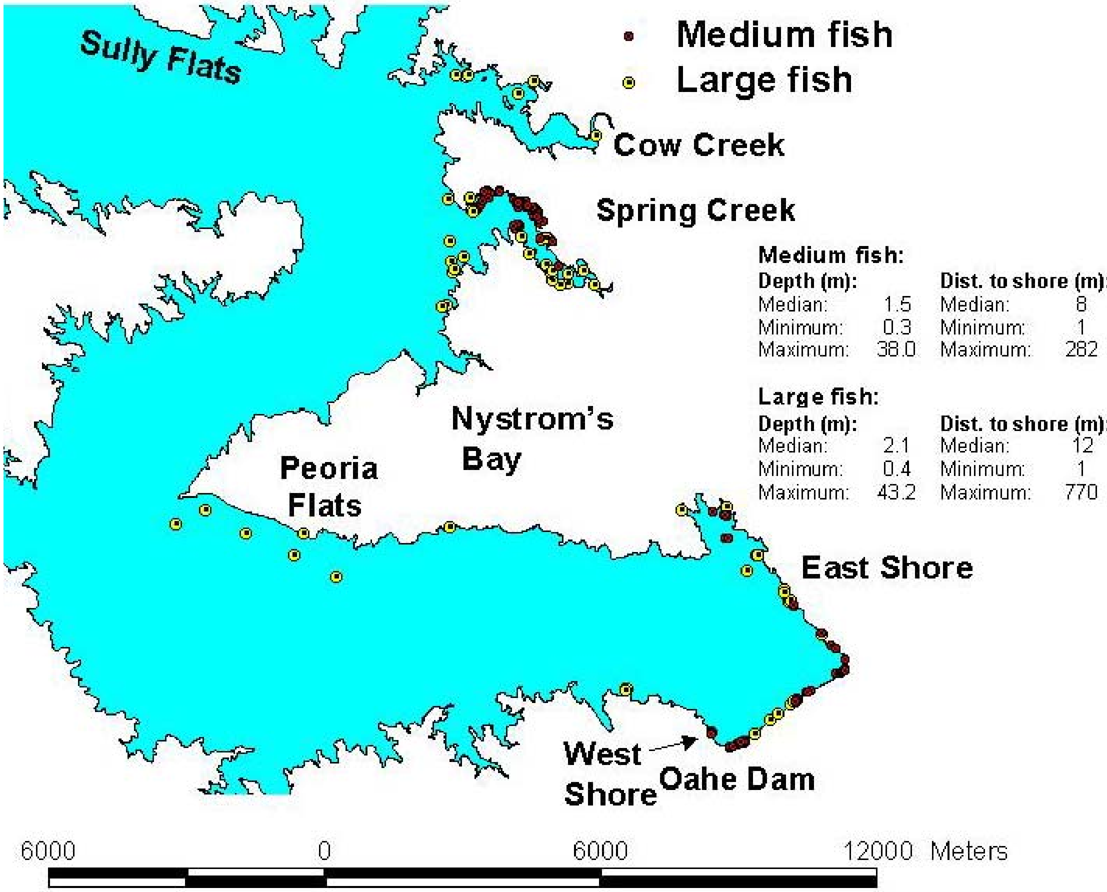

Figure 10. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass, implanted with ultrasonic transmitters, in lower Lake Oahe SD, during the spawning-and-rearing period (June 20 to July 15) of 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

The movement of large smallmouth bass out of Spring Creek and away from Oahe Dam, to main lake points and flats (Figure 11) characterized the change from the spawning-and-rearing period to the summer period. In general, large smallmouth bass established home ranges at Peoria or Sully Flats (Figure 1) or on main lake points between Spring Creek and Nystrom's Bay. A few large smallmouth bass did establish summer home ranges on the face of Oahe Dam and in Spring Creek. Some distribution of medium smallmouth bass away from Oahe Dam to main lake points and submerged islands at East Shore and along the south shore of the reservoir also occurred during the summer period (Figure 11). The median depth occupied by medium smallmouth bass during the summer period was 1.8 m, similar to that documented for the spawning-and-rearing period. While medium smallmouth bass were no deeper during the summer period, they were further from shore. Median distance to shore for medium smallmouth bass approximately doubled from 8 m during the spawning-and-rearing period to 15 m during the summer period (Figure 11). Large smallmouth bass were both deeper and further from shore during the summer period than during the spawning-and-rearing period and when compared to medium fish during the summer period. Median depth of large smallmouth bass increased from 2.1 m during the spawning-and-rearing period to 4.1 m during the summer period and distance to shore increased from 12 m to 50 m (Figures 10 and 11). Establishment of summer home ranges by large fish on long, shallow sloping main-lake points and flats resulted in the median distance to shore of large fish greatly increasing, while fish were still located relatively shallow (<5-m deep).

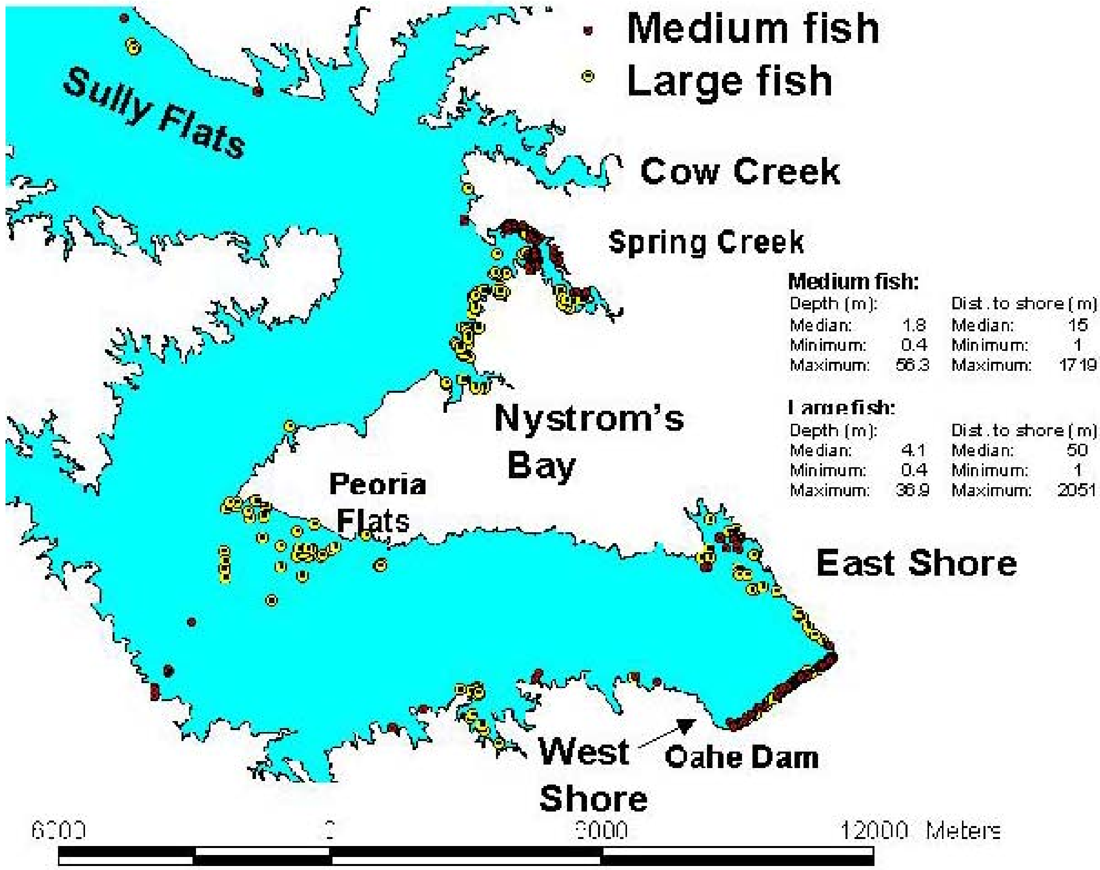

Figure 11. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass, implanted with ultrasonic transmitters, in lower Lake Oahe SD, during the summer period (July 15 – September 30) of 1996. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

The abrupt movement of large smallmouth bass from summer home range areas in the main lake back to either Spring Creek or Oahe Dam characterized transition from the summer period to the fall-and-over-winter period (Figure 12). This pattern of movement supports the theory that smallmouth bass have a strong homing tendency, as all large smallmouth bass still containing transmitters returned to the general area where they were implanted with transmitters in late May and early June to over-winter (Figure 12). Median bottom depth at fish locations increased from 1.8 m and 4.1 m during the summer period to 9.4 m and 10.7 m for the fall-and-over-winter period, for medium and large smallmouth bass, respectively. Median distance to shore increased from 15 m and 50 m for the summer period to 43 m and 78 m for the fall-and-over-winter period, for medium and large smallmouth bass respectively (Figure 12). No substantial changes in smallmouth bass locations occurred during the fall-and-overwinter period, supporting the theory that over winter, smallmouth bass seek out a refuge and remain in a torpor-like state (Coble 1975) during the winter. Kolok (1991) noted that when water temperatures were <8 ^{o}C, smallmouth bass were predominantly inactive. Smallmouth bass in Trinity Reservoir, California, also were located deeper during the winter than during other periods of the year (Cross 1991), supporting the idea that smallmouth bass occupy a deep water refuge during the overwinter period. A similar pattern in smallmouth bass depth occupied and distance to shore was observed in Meredith Reservoir, Texas, where maximum distances to shore and depth were documented during the winter and summer months (Kraii et al. 1991).

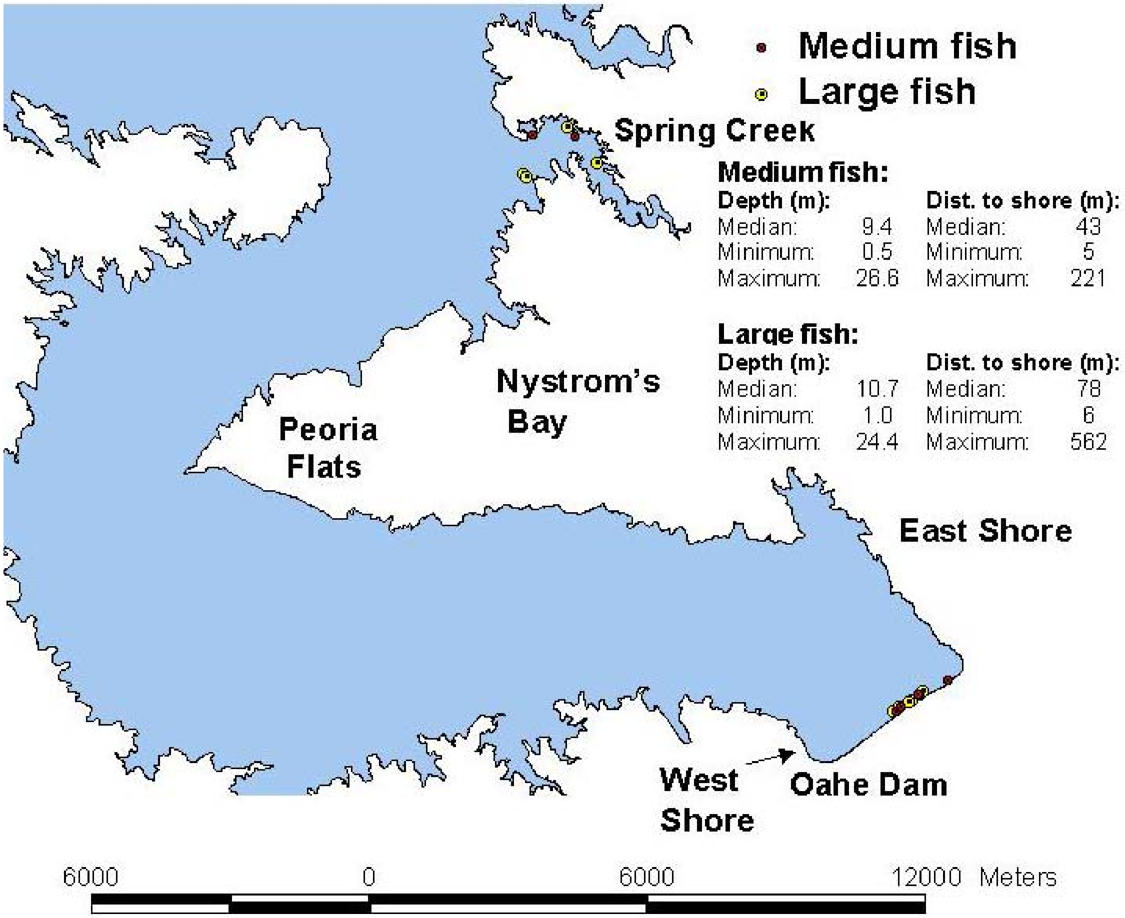

Figure 12. Documented locations and bottom depth and distance to shore for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass, implanted with ultrasonic transmitters, in lower Lake Oahe SD, during the fall-and-over-winter period (October 1 to March 31) of 1996-1997. Smallmouth bass were located using a directional hydrophone and geographic positions were recorded using a Global Positioning System unit.

Cover Use

The percentage of smallmouth bass locations where cover was used was higher ($P<0.01$, 1 d.f.) for medium smallmouth bass than for large smallmouth bass, during all months in the June-October 1996 period (Table 5; Figure 13). Percent of locations where cover was used peaked in June and October for large smallmouth bass. Cole (1994) also documented lower frequencies of cover use during the summer for the larger smallmouth bass implanted with transmitters in Green Lake, Maine. Higher frequencies of cover use have been documented for smallmouth bass 10-15-cm in length versus larger bass and for all sizes of smallmouth bass during daylight periods (Reynolds and Casterlin 1976). Lower frequencies of cover use were documented during late summer than in early summer for all sizes of smallmouth bass studied in Green Lake, Maine (Cole 1994). Peaks in percent cover use for medium smallmouth bass occurred during June and August, although values for all months from June to October were above 60% (Table 5; Figure 13). Cover used by smallmouth bass was classified as one of four types of cover: rip-rap, rock, trees and brush, and submerged aquatic vegetation. The percentages of locations for smallmouth bass of each length group where each type of cover was used for the May to October 1996 period, appear in Table 6 and Figure 14. Because approximately half of the smallmouth bass implanted with ultrasonic transmitters were implanted at Oahe Dam, it is not surprising that rip-rap was highly used as cover during June-October 1996. Percent use of rip-rap by large fish was significantly lower than for medium fish during all months that both length groups were studied during 1996 ($P<0.01$, 1 d.f.). Shortly after large smallmouth bass moved shallow in late May 1996 at Oahe Dam, many of them left the rip-rap of the dam and proceeded along the south/west and east shores of the reservoir to natural habitat areas (Figure 3). The peak in percent of locations where rip-rap was used as cover by large smallmouth bass occurred in September and October as large smallmouth bass implanted with ultrasonic transmitters at Oahe Dam returned to the dam to over-winter (Table 6; Figures 14). Higher percentage of observations where rip-rap was used by medium fish is not surprising, as medium fish were more likely to remain in the area where they were tagged. Some movement of medium smallmouth bass from the rip-rap of Oahe Dam to natural habitat areas did occur after June 1996, but percent use of rip-rap steadily increased from July to October (Table 6; Figure 14). As for large smallmouth bass, high use of rip-rap in September and October corresponded with the return of fish to Oahe Dam for over-wintering. Use of rock as cover by smallmouth bass did not differ between length groups (P=0.20, 1 d.f.) but did differ among months for both length groups studied (P<0.01, 4 d.f. in both cases). Use of rock as cover by both length groups of smallmouth bass exhibited a generally increasing trend from June to October 1996 (Table 6; Figure 14). Smallmouth bass implanted with transmitters at Spring Creek were generally associated with rock cover during the fall-and-overwinter period, because these fish generally over-wintered along steep drop offs either within Spring Creek or immediately outside of Spring Creek. Other authors have documented use of rock as cover by smallmouth bass. Smallmouth bass in Meredith Reservoir, Texas, were most commonly associated with rock structure or submerged humps (Kraii et al. 1991).

The open water periods of 1996 and 1997 were years of high water levels on Lake Oahe and this is reflected in the high percent use of flooded trees and brush by smallmouth bass (Table 6; Figure 14). Use of flooded trees and brush as cover was greater for medium smallmouth bass (P<0.01, 1 d.f.). Use of flooded trees and brush by large smallmouth bass peaked during the June 1996 spawning period. Use of flooded trees and brush as cover by medium smallmouth bass was high (29.4% to 37.0%) during the spawning and summer periods of 1996 (June-August) but decreased as fish moved deeper in September (Table 6; Figure 14). Submerged aquatic vegetation was only present in Lake Oahe in small patches in shallow areas protected from wave action, during 1996 and 1997. However, both length groups of smallmouth bass studied did utilize aquatic vegetation as cover (Table 6; Figure 14). Again, large smallmouth bass only used aquatic vegetation as cover during the spawning-and-rearing period of 1996 (June and July).

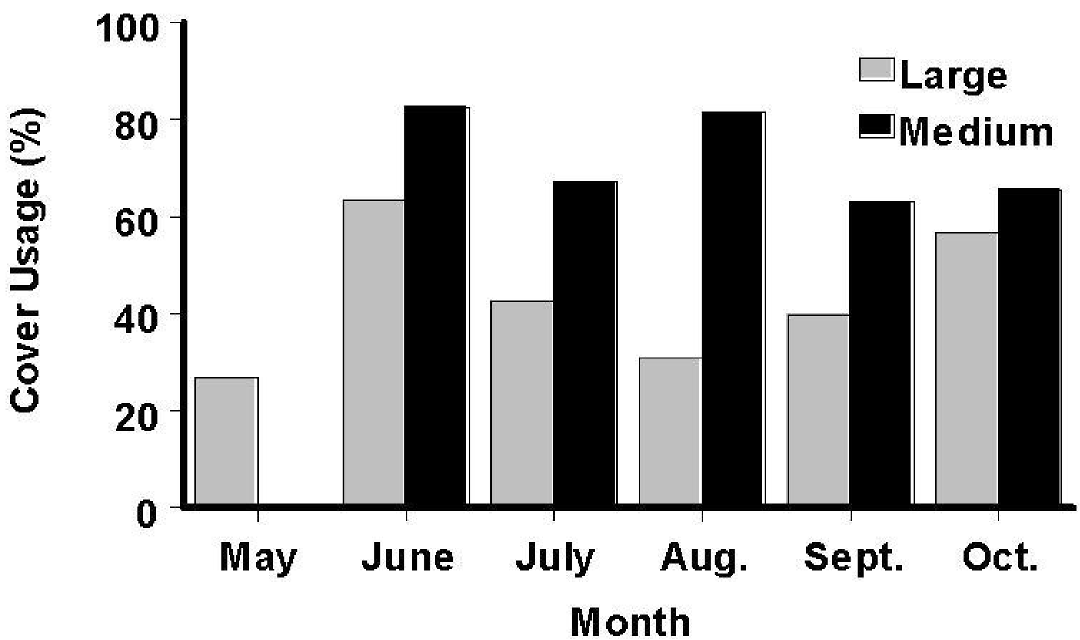

Figure 13. Percentage of all medium (240-290 mm) and large (≥ 350 mm) smallmouth bass locations, where cover was being used, by month, from May through October 1996.

Table 5. Percent cover usage, by fish size, for medium (240-290 mm) and large (≥350 mm) smallmouth bass implanted with ultrasonic transmitters and tracked from May 1996 through October 1996, in lower Lake Oahe, South Dakota. N is the total number of fish locations.

Month	**Percent cover use**					
	Large		**Medium**		**Combined**	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
May 96	30	26.7	-----	-----	-----	-----
June 96	99	63.6	160	82.5	259	75.5
July 96	81	42.7	131	67.2	212	58.0
August 96	139	30.9	189	81.4	328	60.4
September 96	154	39.8	168	63.2	322	52.0
October 96	60	56.7	61	65.6	121	61.2

Table 6. Percent of total cover use, by cover type, for medium (240-290 mm) and large (≥350 mm) smallmouth bass implanted with ultrasonic transmitters and tracked from May 1996 through October 1996, in lower Lake Oahe, South Dakota. N is the number of fish using cover during the specified month.

Fish size	**Month**	**N**	**Percent total cover use**			
			Rip-rap	**Rock**	**Trees/brush**	**Vegetation**
Large Fish	May	30	6.7	10.0	10.0	0.0
	June	99	11.1	2.0	38.4	10.1
	July	81	16.0	4.9	9.9	8.6
	August	139	7.2	8.6	9.4	1.4
	September	154	24.0	10.4	4.5	0.0
	October	60	31.7	16.7	8.3	0.0
Medium fish	May	0	-----	-----	-----	-----
	June	160	47.5	1.25	29.4	0.6
	July	131	24.4	6.1	31.3	3.8
	August	189	34.4	4.8	37.0	0.5
	September	168	41.1	10.7	9.5	0.6
	October	61	45.9	13.1	3.3	0

Hourly Movement Rates

Smallmouth bass median hourly movement rates were closely related to seasonal patterns of habitat use and movements between home ranges established for seasonal periods. For all months during the June-October 1996 period, except June, monthly median hourly movement rates were greater for large smallmouth bass (Table 7; Figure 15). Low median hourly movement rates for large smallmouth bass in May, may signify that smallmouth bass in Lake Oahe overwinter near areas where spawning and rearing home ranges are established. Kraii et. al (1991) noted movements of 5-6 km during the spring and assumed these movements were related to spawning activity. High levels of activity during May were also noted by Gerber and Haynes (1988) in South-central Lake Ontario and may indicate that over-wintering habitat areas were not located near spawning habitat areas. It is generally accepted that the larger smallmouth bass in a population are the first fish to spawn (Shuter and Ridgway 1991). Lower hourly movement rates for large smallmouth bass during June 1996 may be the result of these fish being actively engaged in the spawning process.

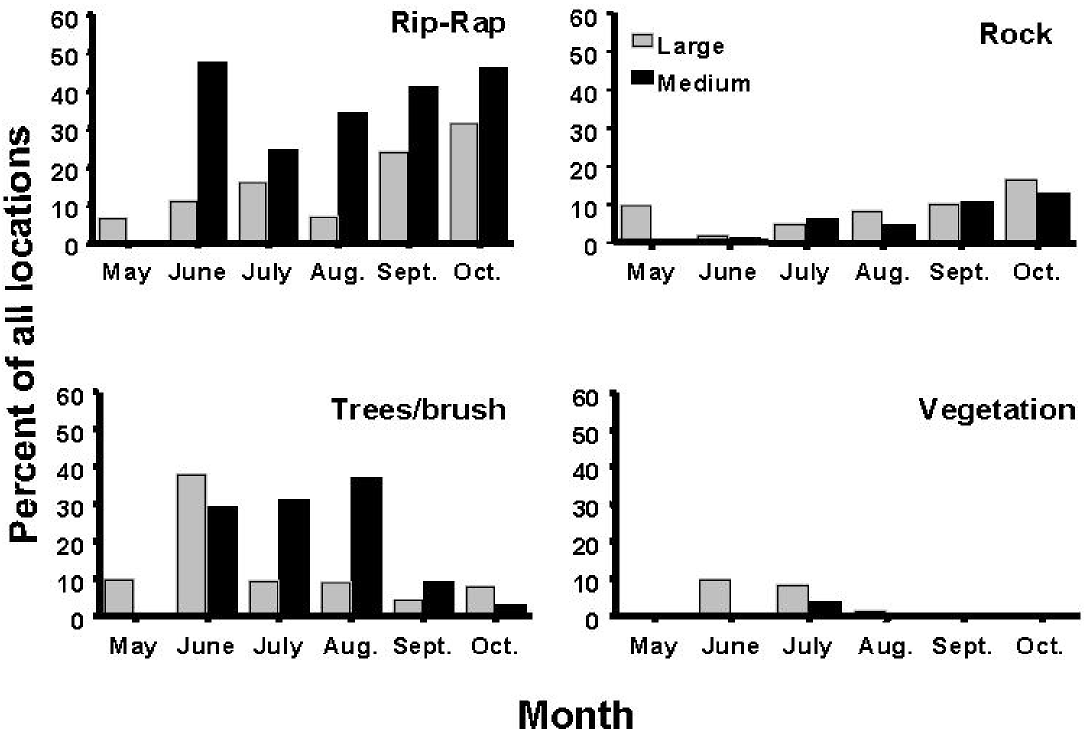

Figure 14. Percentage of all medium (240-290 mm) and large (≥ 350 mm) smallmouth bass locations, where the specified types of cover was being used, by month, from May through October 1996.

Males guarding nests should have little net movement once a nest site is established. The increase in median-hourly-movement rates for large smallmouth bass from 4.4 m/h in June to 18.2 m/h in July reflects the movement of large fish from spawning and rearing areas to summer home ranges and an increase in activity, as large smallmouth bass are actively searching for food rather than guarding a nest. Results of a study by Gerber and Haynes (1988) were similar to those of my study, as an increase in activity of smallmouth bass in Lake Ontario occurred after the spawning and rearing period, possibly related to an increase in feeding activity and the establishment of summer home ranges.
The lower median-hourly-movement rate for large smallmouth bass in August may be due to fish simply occupying a home range area rather than travelling between home range areas. The peak in median-hourly-movement rates for large smallmouth bass in September and October is likely associated with large-scale movements from summer home ranges back to established over-wintering areas and a possible increase in feeding activity as water temperatures decreased. Kraii et. al (1991) and Peterson and Myhr (1976) documented peaks in activity associated with the spring (prespawn; travel to spawning areas) and fall (travel to overwintering areas) periods of the year.

Peaks in diel median hourly movement rates for large smallmouth bass occurred during the rise-day period and at sunset, while peaks in diel median hourly movement rate for medium fish occurred at sunrise and sunset (Table 8; Figure 16), for the May-October 1996 period. Crepuscular peaks in diel activity have been noted by a number of authors (Emery 1973; Reynolds and Casterlin 1976; Helfman 1981; Todd and Rabeni; 1989; Beam 1990). However, Gerber and Haynes (1988) documented a peak in smallmouth bass activity in midday for fish in South-central Lake Ontario. In my study, the lowest median hourly movement rates occurred during night for both length groups of smallmouth bass studied

Table 7. Median hourly movement rates (m\h) between successive smallmouth bass locations and approximate 95% confidence intervals for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters, on lower Lake Oahe, South Dakota from May through October 1996. N is the number of pairs of observations.

Fish size	**Month**	**N**	**Median hourly movement rate**	**95% confidence limit**	
				Lower limit (m)	**Upper limit (m)**
Medium	May	-----	-----	-----	-----
	June	87	6.3	5.0	7.5
	July	87	6.7	3.4	14.1
	August	135	5.8	3.8	8.7
	September	99	8.9	7.2	14.4
	October	18	13.2	6.4	24.7
Large	May	12	4.7	2.0	22.5
	June	48	4.4	2.6	16.2
	July	38	18.2	6.6	102.0
	August	87	10.8	7.3	28.5
	September	90	21.0	10.0	32.5
	October	23	22.7	5.1	37.6
Combined	May	12	4.7	2.0	22.5
	June	135	6.2	4.6	7.4
	July	125	10.1	5.0	16.0
	August	222	7.5	5.5	11.3
	September	189	13.9	10.5	18.5
	October	41	15.3	7.3	30.1

Most authors, with the exception of Peterson and Myhr (1976), noted that smallmouth bass were relatively inactive at night (Emery 1973; Reynolds and Casterlin 1976; Helfman 1981; MacLean et. al 1982; Gerber and Haynes 1988; Todd and Rabeni; 1989; Beam 1990). With regard to monthly patterns in median hourly movement rates in Lake Oahe, large smallmouth bass were generally more active than medium fish during all diel periods except set-night and night (Table 8). Helfman (1981) noted that smallmouth bass >300 mm in length were active later in the evening and earlier in the morning than smaller bass, suggesting an increase in activity with increasing fish size. Other authors have also documented an increase in smallmouth bass activity with increasing fish size (Beam 1990; Cole 1994). However, no relationship between daily or seasonal movement or activity and fish size was documented in the study by Gerber and Haynes (1988).

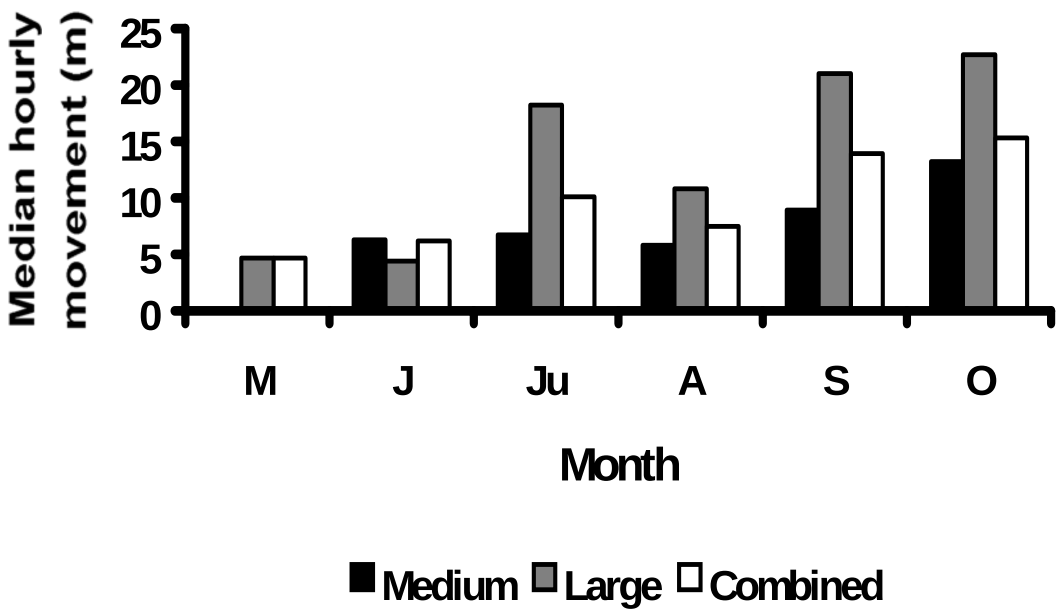

Figure 15. Median hourly movement rates, by month, for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters, from May through October 1996.

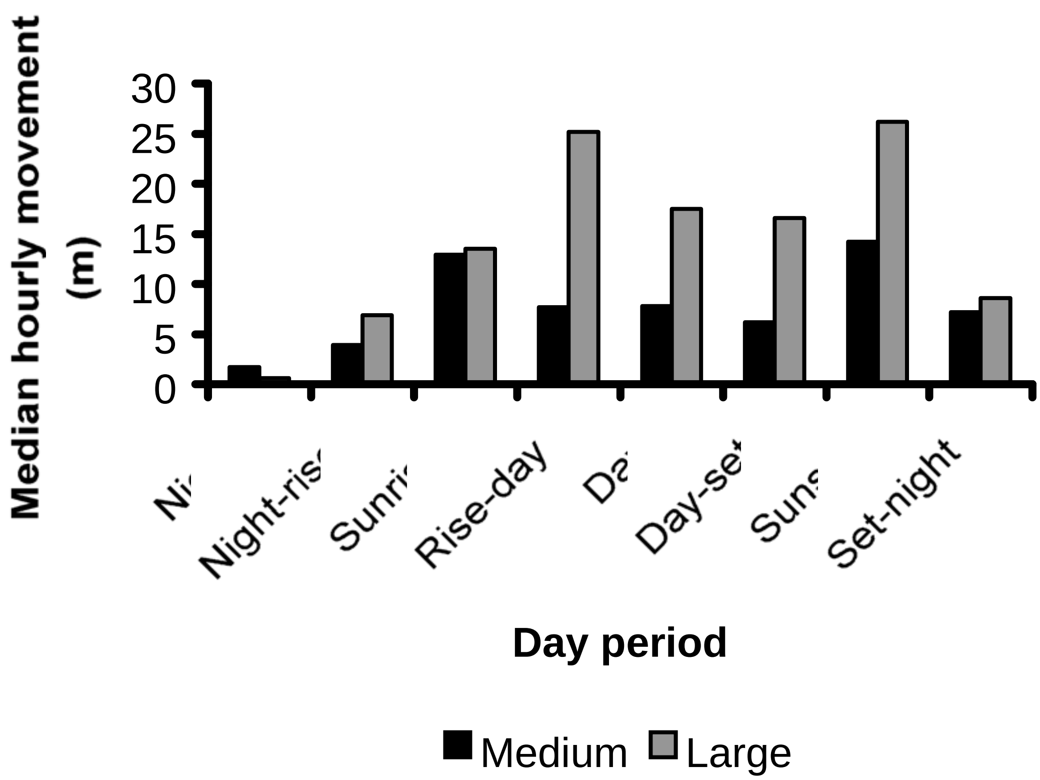

Figure 16. Median hourly movement rates, by day period, for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters, from May through October 1996.

Table 8. Median hourly movement rates (m\h) between successive smallmouth bass locations, by diel period and fish size, months combined, and approximate 95% confidence intervals, for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters, on lower Lake Oahe, South Dakota from May through October 1996. Values for medium fish are for the June through October period. N is the number of pairs of observations. Sunrise and sunset periods include 2-h before and after established sunrise or sunset times.

Fish size	Diel Period	N	Median hourly movement	95% confidence limit	
				Lower limit	Upper limit
Medium	Night	10	1.7	0.1	33.3
	Night-rise	68	3.9	2.6	5.9
	Sunrise	59	12.9	6.2	17.6
	Rise-day	68	7.7	5.3	13.9
	Day	94	7.8	5.0	17.9
	Day-set	65	6.2	4.4	11.7
	Sunset	33	14.2	7.9	17.5
	Set-night	23	7.2	2.5	10.9
Large	Night	10	0.6	0.3	8.6
	Night-rise	45	6.9	3.9	18.9
	Sunrise	33	13.5	8.3	38.1
	Rise-day	41	25.2	12.5	48.6
	Day	61	17.5	5.9	57.3
	Day-set	53	16.6	6.3	34.3
	Sunset	24	26.2	6.2	52.4
	Set-night	24	8.6	3.5	15.6
Combined	Night	20	1.5	0.5	8.6
	Night-rise	113	4.9	3.4	6.7
	Sunrise	92	13.2	7.9	16.6
	Rise-day	109	12.7	7.5	18.
	Day	155	9.7	6.2	18.1
	Day-set	118	8.3	5.8	16.6
	Sunset	57	15.3	11.4	24.7
	Set-night	47	7.6	3.9	9.9

Environmental Effects on Activity, Bottom Depth and Temperature Occupied

Not surprisingly, occupied depth and distance to shore were strongly correlated for both length groups of smallmouth bass for all months during the June-October 1996 period and overall (P<0.001 for all tests, r_s range of 0.31 to 0.82). As distance to shore increased so did bottom depth occupied (Figure 9). Spearman's Rho correlation coefficients (r_s) for tests of occupied depth vs. distance to shore were higher for large smallmouth bass from June-August 1996 (r_s range of 0.58 to 0.82), but medium fish coefficients were higher during September and October. Bottom depth occupied and distance to shore were significantly negatively correlated with temperature occupied, for both length groups of smallmouth bass studied, during July-September 1996, the period of summer thermal stratification in Lake Oahe (Figure 8). As the summer progressed and water temperature increased, smallmouth bass were located in deeper water and further from shore. However, while significant because of high sample size, r_s values for the May-October 1996 period were low (r_s range of –0.10 to –0.41), suggesting other variables, such as light intensity and the presence of food and cover, may also be important variables determining smallmouth bass location. Surface light intensity was significantly correlated with occupied depth, for both length groups of smallmouth bass studied, during June and August, though, r_s values were low, ranging between 0.17 and

0.27 during these months. In Green Lake, Maine, depth occupied by smallmouth bass was not significantly correlated with surface light intensity during the June-September period (Cole 1994). However, large smallmouth bass located in deep water areas in midday were almost always then located in shallower water at dawn and dusk. In my study on lower Lake Oahe, distance to shore and surface light intensity were not significantly correlated during the June-October 1996 period for either length group of smallmouth bass, except for medium fish in June (P<0.05, r_s=0.16, n=133) and August (P<0.05, r_s=0.14, n=184) and for large fish in September (P<0.03, r_s=0.21, n=139). It has been suggested that deeper water may be used instead of physical cover, by smallmouth bass during daylight periods (Coble 1975) and that depth occupied may be greater during the day than at night (Helfman 1981). Cole (1994) also hypothesized that because light intensities were lower in deep water, prey may be more vulnerable to predation. Barometric pressure and hourly movement rates were not significantly correlated, with each other, for either length group of smallmouth bass during the May-October 1996 period except for medium-length fish during June (P<0.01, r_s=-0.32, n=87). A complete list of correlations between characteristics of smallmouth bass habitat use and movement and environmental variables appears in Appendix 2.

Home Range Characteristics

During the course of the study, smallmouth bass implanted with transmitters appeared to either be travelling from one seasonal home range to another or occupying a seasonal home range. Periods of movement between occupied habitat areas were abrupt and distinct from periods when fish occupied a home area. It is believed that an individual smallmouth bass will occupy a number of different home ranges throughout the year (spawning, summer, over-winter etc.) and that periods of movement may separate use of home ranges (Warden and Lorio 1975).

Though many of the smallmouth bass implanted with ultrasonic transmitters likely established home ranges during each of the seasonal periods described, only home ranges with a sufficient number of observations and tracking dates (> 15 observations, 5 tracking dates) to generate meaningful statistics for home range characteristics are included in this report. Six medium smallmouth bass home ranges and three large smallmouth bass home ranges are described in detail (Tables 9 and 10). Bottom depth contour and substrate and cover maps for two medium fish and two large fish summer home ranges are presented in Figures 17-20.

Home range area and core area estimates for large smallmouth bass summer home ranges were larger than estimates for medium fish summer home ranges (Table 9). The trend of increasing home range size with increasing fish size has been documented in other studies (Beam 1990; Cole 1994) and is likely due to the higher energy (prey) demand of larger fish (McNab 1963). Larger animals need a larger area to gather food than do smaller animals, unless food is abundant (McNab 1963). The range of home range area estimates in my study on Lake Oahe (Table 9) was similar to that generated for smallmouth bass in Meredith Reservoir, a 3,500-ha reservoir in Texas (Kraii et al. 1991).

Table 9. Home range characteristics for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters that established definitive home ranges during 1996. Home range boundaries were calculated using the adaptive-kernel method with 90% of observations included in home range boundaries and 50% of observations included in core area boundaries. Fall/ow is the fall-and-over-winter seasonal period and No. of obs. is the number of observations included when calculating home range estimates.

Fish number	Fish size	Seasonal period	Tracking history				Area estimates (ha)	
			No. of obs .	No. of obs. dates	Begin date	Ending date	Home-range	Core area
88	medium	summer	16	6	7/9	8/22	12.0	1.4
249	medium	summer	38	10	8/7	10/28	1.6	0.4
267	medium	summer	31	10	7/3	9/12	4.8	0.4
357	medium	summer	35	14	7/9	10/28	2.7	0.7
88	medium	fall/ow	20	8	9/9	12/9	4.6	1.3
465	medium	fall/ow	18	8	9/10	10/28	0.8	0.2
274	large	summer	32	13	7/1	9/29	22.4	1.5
2226	large	summer	27	13	7/1	9/24	39.4	11.0
2244	large	summer	27	11	6/28	9/28	34.5	3.8
			Distance to shore (m)			Depth (m)		
			Median	Minimum	Maximum	Median	Minimum	Maximum
88	medium	summer	281	196	333	8.0	5.2	13.5
249	medium	summer	17	3	30	1.1	0.5	6.2
267	medium	summer	6	2	27	2.0	1.2	7.5
357	medium	summer	16	3	45	8.1	0.7	15
88	medium	fall/ow	44	15	75	14.1	5.8	26.6
465	medium	fall/ow	108	47	118	8.3	2.8	16.5
274	large	summer	34	1	286	3.8	0.5	14.2
2226	large	summer	89	35	225	5.9	2.1	16.5
2244	large	summer	7	1	25	2.1	0.6	9.1

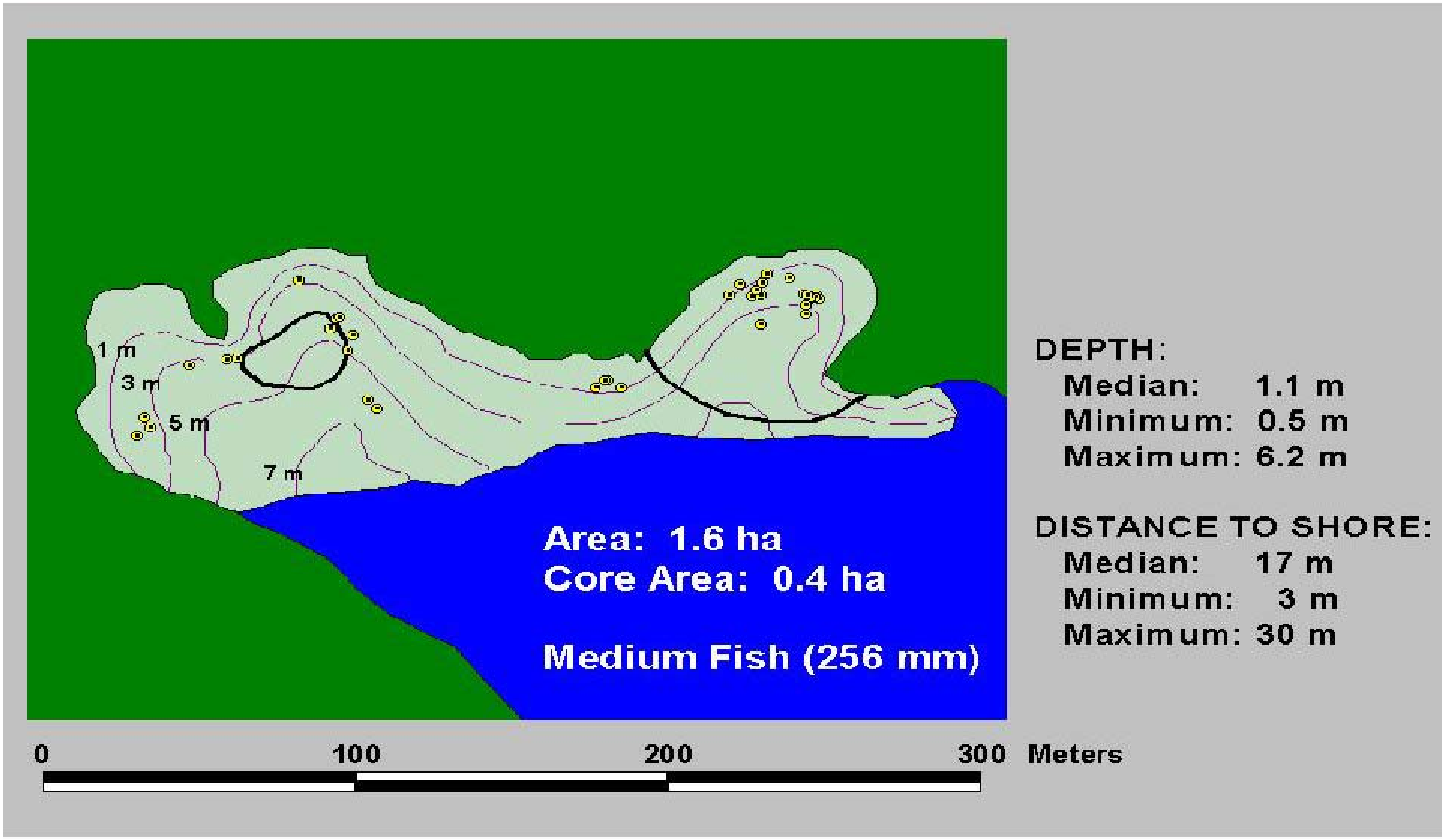

Figure 17. Bottom depth contour and substrate and cover maps for the summer 1996 home range of a medium (240-290 mm) smallmouth bass implanted with transmitter number 249. This smallmouth bass was implanted with a transmitter on June 3, 1996 in Spring Creek and this home range was established on the north shore of Spring Creek, in the embayment directly east of Spring Creek marina. The thick black line within the home range boundary represents core area boundaries.

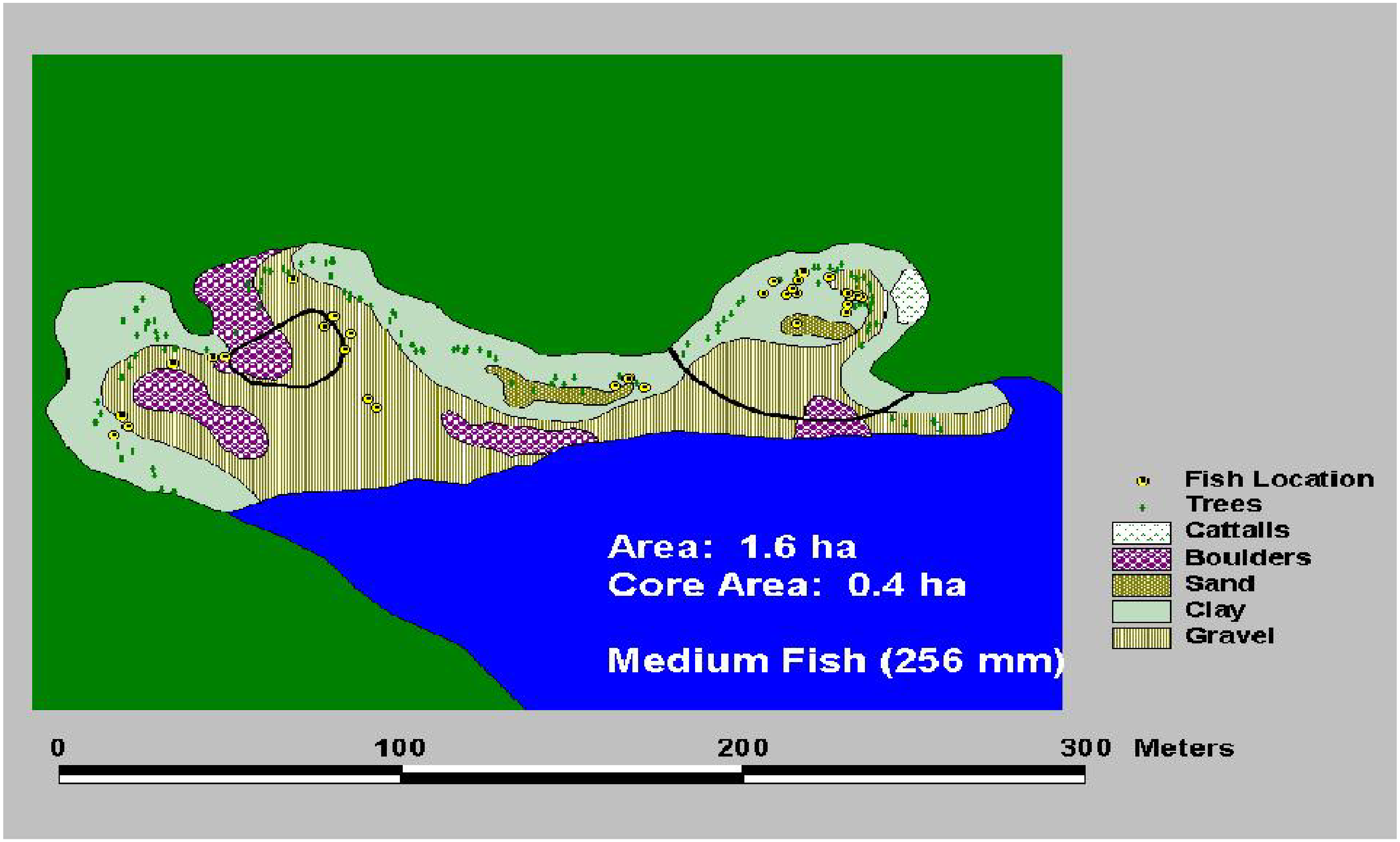

Figure 17 continued…

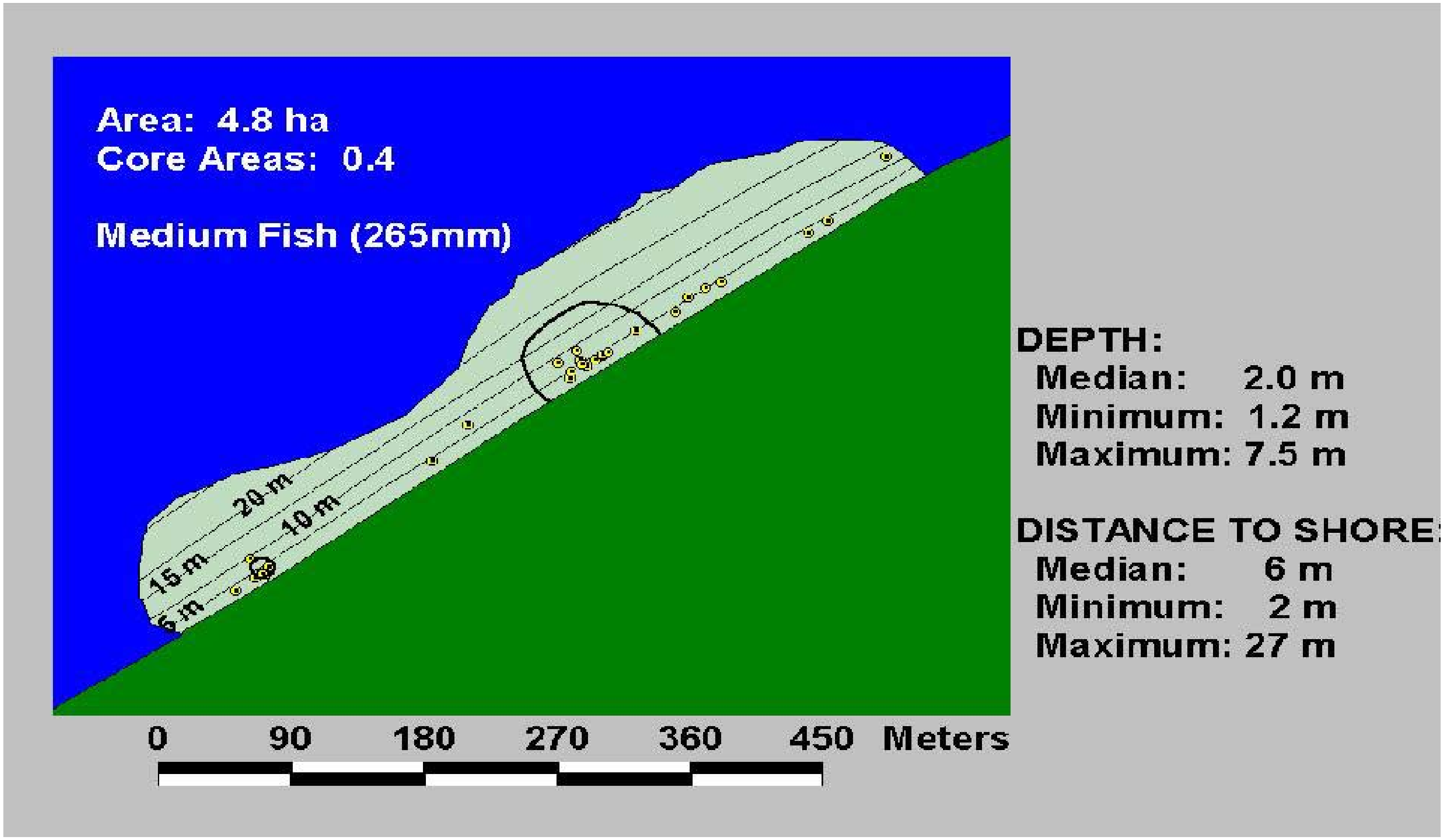

Figure 18. Bottom depth contour and substrate and cover maps for the summer 1996 home range of a medium (240-290 mm) smallmouth bass implanted with transmitter number 267. This smallmouth bass was implanted with a transmitter on June 5, 1996 at Oahe Dam and this home range was established on the rip-rap of the face of Oahe Dam. The thick black line within the home range boundary represents core area boundaries.

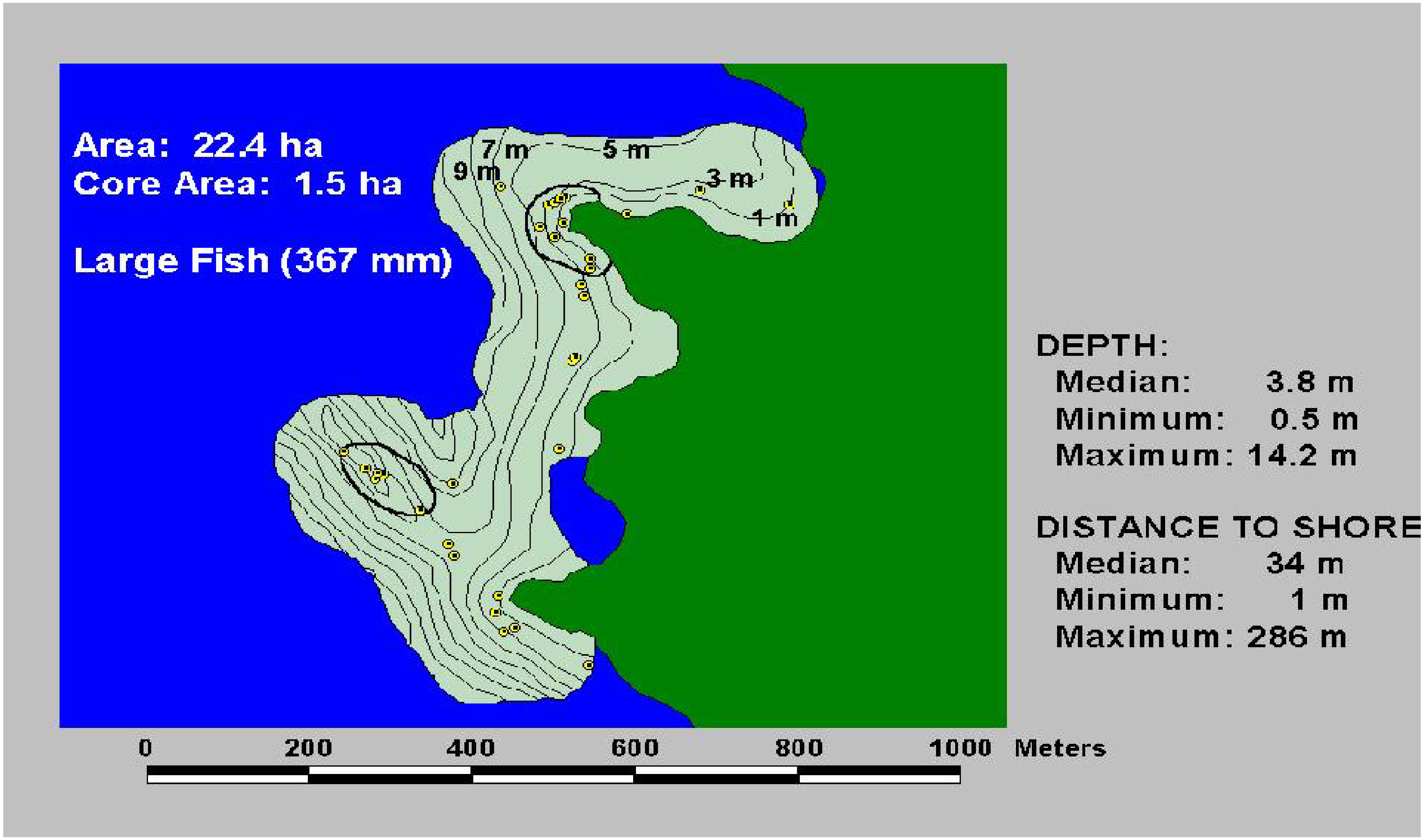

Figure 19. Bottom depth contour and substrate and cover maps for the summer 1996 home range of a large (≥ 350 mm) smallmouth bass implanted with transmitter number 274. This smallmouth bass was implanted with a transmitter on May 14, 1996 at Oahe Dam and this home range was established on the east point of Nystrom's Bay. The thick black line within the home range boundary represents core area boundaries.

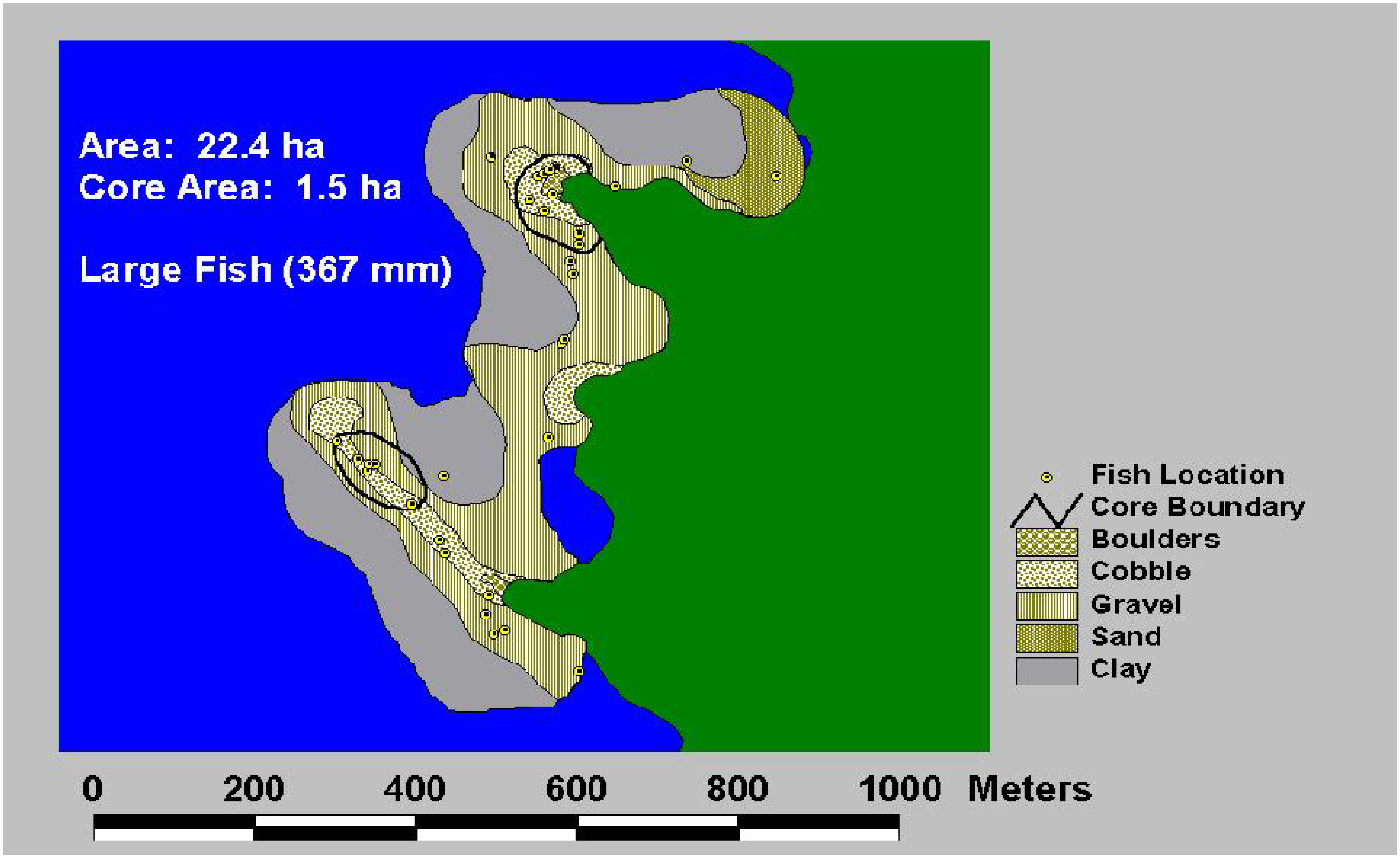

Figure 19 continued…

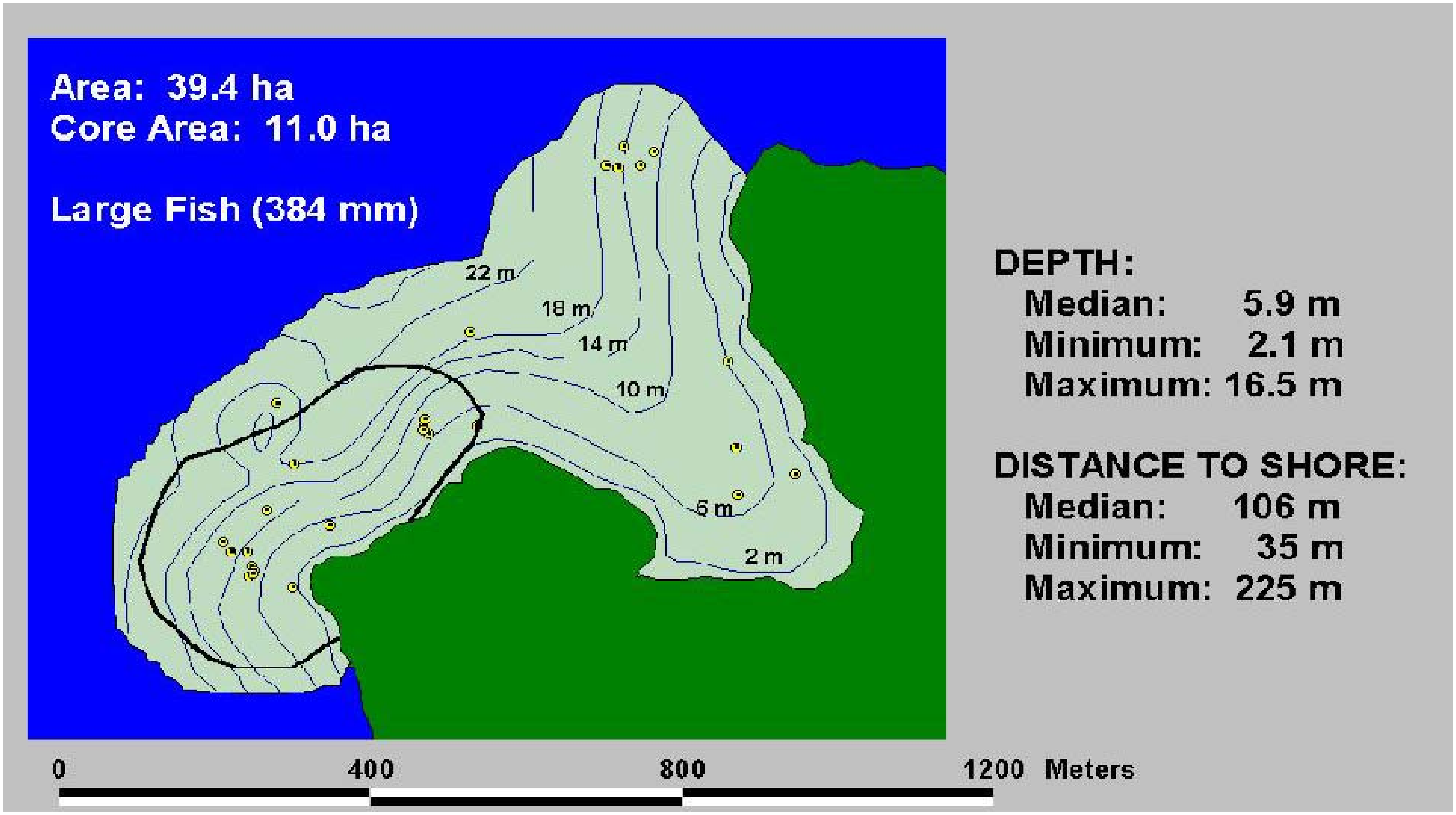

Figure 20. Bottom depth contour and substrate and cover maps for the summer 1996 home range of a large (>350 mm) smallmouth bass implanted with transmitter number 2226. This smallmouth bass was implanted with a transmitter on May 13, 1996 at Oahe Dam and this home range was established between Nystrom's Bay and Spring Creek. . The thick black line within the home range boundary represents core area boundaries.

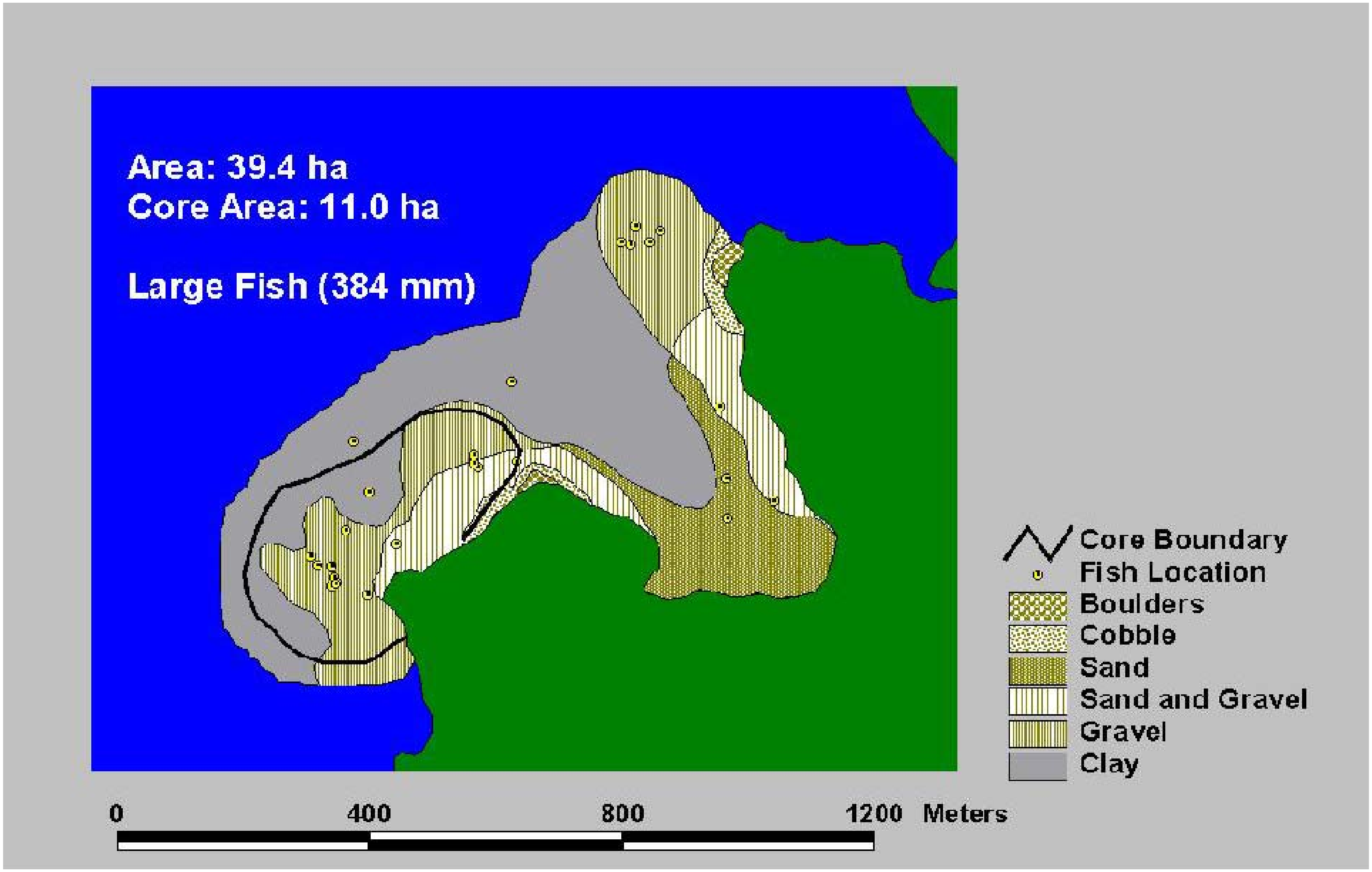

Table 20 continued...

Distances to shore for the summer home range of medium fish number 88 were quite high (Table 9), as this smallmouth bass established a summer home range on a submerged island near East Shore. The corresponding fall-and-over-winter home range of medium fish 88 was on Oahe Dam, where it had been implanted with a transmitter on June 5, 1996 (Appendix 1). Large ranges in minimum and maximum distances from shore for large fish numbers 274 and 2226 are a result of these fish establishing summer home ranges on long, shallow main-lake points between Nystrom's Bay and Spring Creek (Table 9).

In general, shapes of home ranges closely followed bottom contours (Figures 17-20), and patterns in available substrate strongly matched bottom contours (Ridgway and Shuter 1996). This explains the strongly linear shape of home ranges mapped in my study, especially along the rip-rap of Oahe Dam (Figure18). The linear shape of smallmouth bass home ranges has also been documented in other studies (Hubert and Lackey 1980; Cole 1994; Ridgway and Shuter 1996).

The primary soil composing the shoreline of lower Lake Oahe is Pierre shale, which is composed primarily of clay. When Pierre shale is eroded by wave action, a fine clay results. Clay in bottom substrates is easily suspended in the water column by wave action, and washed into deeper water where it settles. The depth to which wave action can suspend clay and wash it into deeper water can be over 7 m. Therefore, the lake bottom in areas < 7-m deep and exposed to frequent wave action is often composed of sand, gravel, rock and rubble substrates (Figures 19 and 20). Smallmouth bass use of relatively shallow water (<7-m deep) may be due to substrates or cover present and available prey resources, rather than a preference for certain depths or temperatures (Bevelhimer 1995, 1996).

Table 10. Home range substrate composition for medium (240-290 mm) and large (≥ 350 mm) smallmouth bass implanted with ultrasonic transmitters that established definitive home ranges during 1996. Home range boundaries were calculated using the adaptive-kernel method with 90% of observations included in home range boundaries and 50% of observations included in core area boundaries. Fall/ow is the fall-and-over-winter seasonal period.

Fish number	Fish size	Seasonal period	Percent substrate composition					
			Clay	Sand	Gravel	Cobble	Boulder	Rip-rap
88	medium	summer	76			24		
249	medium	summer	40	3	43		13	
267	medium	summer						100
357	medium	summer						100
88	medium	fall/ow						100
465	medium	fall/ow	24		56	13	7	
274	large	summer	42	6	43	9		
2226	large	summer	54	11	32	2	1	
2244	large	summer						100
			Core area Percent substrate composition					
			Clay	Sand	Gravel	Cobble	Boulder	Rip-rap
88	medium	summer	35			65		
249	medium	summer	44	4	40	9		
267	medium	summer						100
357	medium	summer						100
88	medium	fall/ow						100
465	medium	fall/ow	18		72			
274	large	summer	3		47	43	6	
2226	large	summer	30		70			
2244	large	summer						100

When examining substrate composition of smallmouth bass home ranges not composed entirely of rip-rap, clay, gravel and cobble substrates were common in all home ranges (Table 10). However, areas of clay are likely rarely used or used because of cover present rather than substrate composition. The greater percent composition of core areas of gravel and cobble substrates supports the theory that clay substrates are not commonly used unless cover is present. Many of the medium smallmouth bass in Spring Creek frequently used flooded trees and brush in protected bays as cover, and this cover was located in areas where clay was the dominant substrate. This was the case for the summer home range of medium fish 249 (Figure 17). Clay was also the predominant substrate in smallmouth bass residence areas in Pickwick Reservoir, Tennessee but rubble and gravel occurred in 70% of residence areas and was highly utilized by smallmouth bass (Hubert and Lackey 1980). Summer home areas of smallmouth bass in South-central Lake Ontario were also centered on areas of rocky substrate (Gerber and Haynes 1988).

The homing ability of smallmouth bass in Lake Oahe is illustrated by large fish 274, which was implanted with an ultrasonic transmitter on May 14, 1996 at Oahe Dam. Large fish 274 established a summer home range on the east point of Nystrom's Bay in 1996 (Figure 19), returned to Oahe Dam to over-winter and then established a summer home range at the same location in 1997. Daily patterns in habitat use were evident when tracking individual smallmouth bass that established home ranges, such as large fish 274 and 2226 (Figures 19 and 20). Both fish 274 and fish 2226 were routinely located in shallower water during night and crepuscular periods than during mid day. The return of all smallmouth bass implanted with transmitters at Oahe Dam, to the dam for overwintering is another example of the homing instinct of smallmouth bass in Lake Oahe. The strong homing nature of smallmouth bass has been documented by a number of authors (Robbins and MacCrimmon 1977; Hubert and Lackey 1980; Blake 1981; Todd and Rabeni 1989; Healey 1990; Ridgway et al. 1991; Ridgway and Shuter 1996). In Lake Opeongo, Ontario, Ridgway et. al (1991) demonstrated strong nest-site fidelity of smallmouth bass, while Ridgway and Shuter (1996) found that 83% of smallmouth bass displaced from their summer home ranges returned to their home range within two weeks. Between 32% and 38% of potamodromous smallmouth bass in Lake Simcoe, Ontario, returned to the same stream to spawn in subsequent years (Robbins and MacCrimmon 1977). These smallmouth bass returned to the exact area of stream used in previous years for spawning.

Structural and Abundance Indices for Electrofishing Surveys

Standardized electrofishing surveys were conducted on the face of Oahe Dam and the north shore of Spring Creek, from mid-May through mid-October 1996, to generate indices of population structure and dynamic characteristics for comparison with smallmouth bass electrofishing susceptibility data. Electrofishing surveys were conducted at each site during seven, 20-d periods (Table 11). Total electrofishing CPUE, which included all smallmouth bass captured, was substantially greater than the sum of large and medium smallmouth bass CPUE for both survey sites and all survey periods, indicating that smallmouth bass < 240 mm TL were abundant in electrofishing samples (Table 11). Total electrofishing CPUE was higher at Oahe Dam than at Spring Creek, for all sampling periods; however, CPUE for large smallmouth bass was higher at Spring Creek during all sampling periods that large smallmouth bass were sampled (Table 11). Higher CPUE of large smallmouth bass in natural bay habitat than in rip-rap habitat was also documented in 1994 on lower Lake Oahe (Lott 1996). Peaks in electrofishing CPUE for large smallmouth bass occurred during the May-June sampling period at both survey sites and then decreased, with no large fish being captured during electrofishing surveys after the June-July period at Oahe Dam and the July-August period at Spring Creek (Table 11). Trends in PSD and RSD-P values were similar to patterns in large smallmouth bass CPUE, with values being higher at Spring Creek and peaking during the May-June period at both survey sites (Table 11). Proportional stock density values were generally lowest during the August-September and September periods, then increased during the September-October period (Table 11). As in my study, fall smallmouth bass electrofishing CPUE was lower than spring CPUE in New York Lakes (Green et. al 1986). Seasonal changes in CPUE of smallmouth bass in nearshore electrofishing surveys, as in my study, may be due to onshore-offshore movements related to spawning (Beamesderfer and Ward 1994).

Table 11. Mean catch per unit effort by fish size, proportional stock density (PSD) and relative stock density of preferred length fish (RSD-P) for nighttime electrofishing surveys at Oahe Dam and Spring Creek. N is the number of electrofishing runs during each 20-d period and N_s is the number of stock-length fish used in calculations of PSD and RSD-P. Total CPUE includes all smallmouth bass captured, not just bass of medium (240-290 mm) or large (≥ 350 mm) size.

Location	20-d period	N	CPUE (Number./h)			Structural indices		
			Medium	Large	Total	N_s	PSD	RSD-P
Oahe Dam	May-June	12	8.00	2.00	104.67	135	9	1
	June-July	4	2.00	0.670	201.00	67	7	1
	July	4	6.00	0.00	277.00	80	3	0
	July-August	6	4.00	0.00	72.67	56	2	0
	August-September	4	6.00	0.00	192.00	80	1	0
	September	6	18.00	0.00	193.33	168	2	0
	September-October	6	14.67	0.00	110.00	86	6	0
Spring Creek								
	May-June	6	6.00	4.67	24.67	35	71	20
	June-July	4	8.67	2.67	52.00	43	30	9
	July	4	4.00	1.6	42.40	24	33	8
	July-August	6	1.33	0.67	24.67	9	22	11
	August-September	4	4.67	0.00	41.33	48	6	0
	September	6	2.67	0.00	43.33	39	8	0
	September-October	6	1.33	0.00	17.33	13	15	0

Electrofishing Susceptibility

Based on information gained from mapping the electric field (Kolz et al. 1995) of the Smith-Root electrofishing boat used in this study, smallmouth bass implanted with sonic transmitters were considered susceptible to electrofishing if they were located within 10 m of shore and ≤ 2-m deep, between sunset and sunrise. Susceptibility of smallmouth bass implanted with ultrasonic transmitters to electrofishing was calculated for all medium or large fish, not only the smallmouth bass that were in the general vicinity of electrofishing survey sites (Oahe Dam and Spring Creek). Susceptibility of medium smallmouth bass to electrofishing was highest for the May-June period then decreased through the July-August period (Table 12, Figure 21). An increase in susceptibility of medium fish to electrofishing was documented for the August-September period, though susceptibility of medium fish then decreased through the September-October period (Table 12, Figure 21). Electrofishing CPUE for medium smallmouth bass at Spring Creek was strongly correlated to susceptibility of medium fish to electrofishing (P<0.03, r_s=0.85, Figure 21). Few medium smallmouth bass implanted with transmitters in Spring Creek left Spring Creek and any natural habitat they may have occupied outside of Spring Creek would be relatively similar to the area electrofished. Medium smallmouth bass CPUE at the face of Oahe Dam initially followed the same pattern as electrofishing susceptibility (June-July 1996) but medium fish electrofishing CPUE and electrofishing susceptibility were not strongly correlated (P>0.10, r_s=-0.09) for the June-October 1996 period (Figure 21). A possible reason for the lack of a significant correlation between medium smallmouth bass electrofishing CPUE and electrofishing susceptibility at the Oahe Dam face may be that medium smallmouth bass implanted at Oahe Dam were more likely to leave the face of the dam and utilize natural habitats during the summer than to remain on the dam face. The increase in electrofishing CPUE of medium smallmouth bass at the face of Oahe Dam after the August-September period, while electrofishing susceptibility was decreasing (Figure 21), may be a result of a large number of medium fish returning to Oahe Dam to over-winter. Even though medium fish, in general, were less susceptible to electrofishing after the August-September period, enough medium fish may have returned to Oahe Dam to increase electrofishing catch rates.

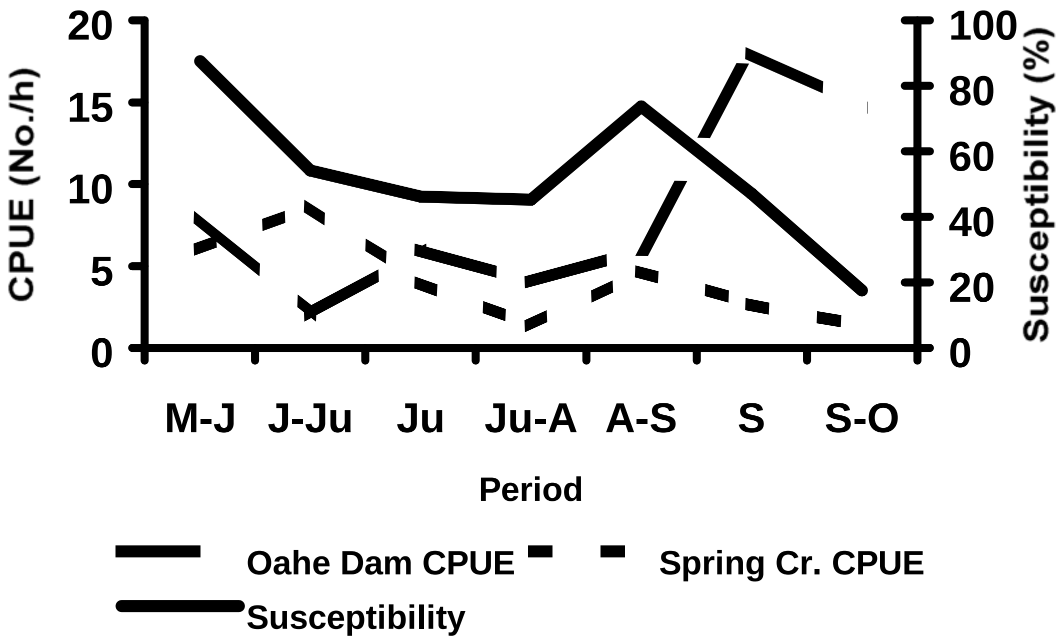

Figure 21. Electrofishing catch per unit effort (CPUE) for medium (240-290 mm) smallmouth bass at Spring Creek and Oahe Dam and electrofishing susceptibility of all medium smallmouth bass implanted with ultrasonic transmitters that were located during nighttime hours, by 20-d period, from mid-May through mid-October 1996. Smallmouth bass were considered susceptible to electrofishing if the bottom depth at their location was < 2-m deep and the location was < 10 m from shore.

Table 12. Electrofishing susceptibility of smallmouth bass implanted with ultrasonic transmitters, by fish size, for 20-day periods, from mid-May through Mid-October, 1996. Smallmouth bass were considered susceptible to electrofishing if they were within 10 m of shore and in water < 2-m deep. Only nighttime locations of smallmouth bass were used. N is the number of fish locations used in analysis.

Twenty-day period	Medium fish		Large fish	
	N	Susceptible (%)	N	Susceptible (%)
May-June	24	87.5	11	72.7
June-July	37	54.1	21	57.1
July	39	46.2	20	30
July-August	31	45.2	15	6.7
August-September	38	73.7	33	18.2
September	34	47.1	34	26.5
September-October	34	17.6	35	14.3

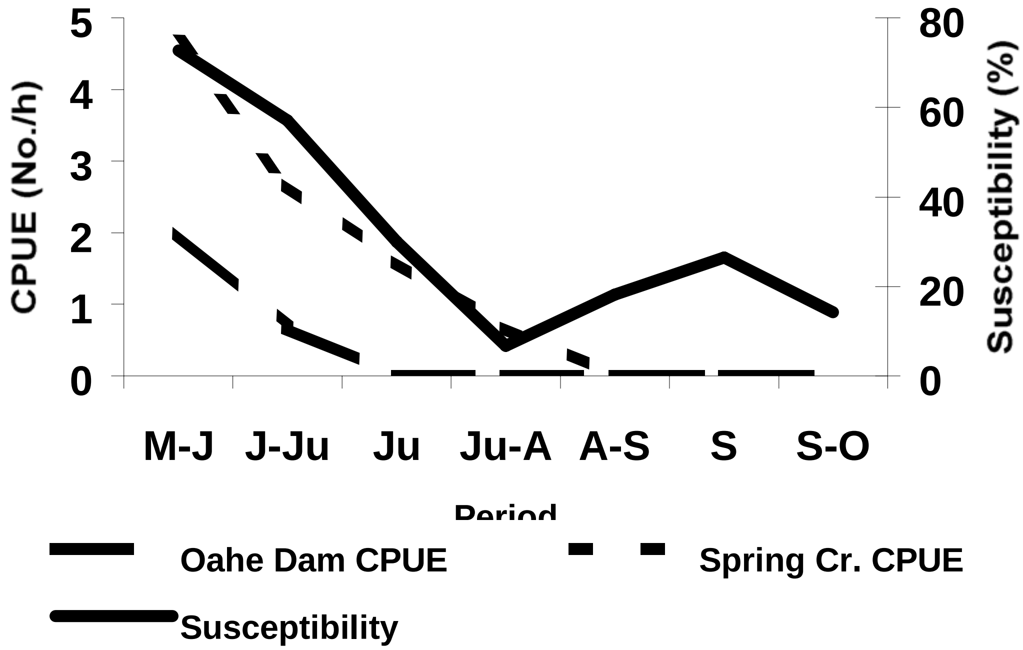

Figure 22. Electrofishing catch per unit effort (CPUE) for large (≥ 350 mm) smallmouth bass at Spring Creek and Oahe Dam and electrofishing susceptibility of all large smallmouth bass implanted with ultrasonic transmitters that were located during nighttime hours, by 20-d period, from mid-May through mid-October 1996. Smallmouth bass were considered susceptible to electrofishing if the bottom depth at their location was < 2-m deep and the location was < 10 m from shore.

Susceptibility of large smallmouth bass implanted with ultrasonic transmitters was significantly correlated with electrofishing CPUE for both the Oahe Dam and Spring Creek sampling sites (P<0.03, r_s=0.80 and $P<0.05$, r_s=0.74, respectively). However, patterns in electrofishing susceptibility and CPUE differed beginning with the August-September period (Figure 22). Even though susceptibility of large smallmouth bass to electrofishing increased after the July-August period, large smallmouth bass were absent from electrofishing samples after the July period and August-September period at Oahe Dam and Spring Creek, respectively. Absence from electrofishing samples in Spring Creek may be partly due to some large smallmouth bass implanted with ultrasonic transmitters establishing fall-and-over-winter home ranges outside of Spring Creek. It is possible that the majority of large smallmouth bass that use Spring Creek during the pre-spawn and spawning-and-rearing periods over-winter outside the bay. These fish would be shallow enough and close enough to shore to be susceptible to electrofishing, but their presence outside of Spring Creek meant that they were not susceptible to capture during established electrofishing runs inside the bay.

Only during the June-July (late June) and September-October sampling periods were electrofishing susceptibility of medium and large smallmouth bass similar (Table 12; Figure 23). During other sampling periods, medium smallmouth bass were more susceptible to capture by electrofishing and were over-represented in electrofishing samples when compared to large smallmouth bass (Figure 23). Beamsderfer and Rieman (1988) suggested that the decreasing vulnerability of smallmouth bass to capture with increasing fish size, may be a result of habitat use patterns. The results of my study support this theory, as large smallmouth bass were located outside of the effective electrofishing zone during periods of time when electrofishing CPUE of large fish was low. The primary concern of fisheries biologists using nighttime electrofishing as the primary technique for surveying smallmouth bass populations is that indices of population size structure (PSD, RSD-P, length frequency) generated from these surveys are often underestimates of true population size structure (Beamesderfer and Rieman 1988; Milewski and Willis 1991; Cole 1994).

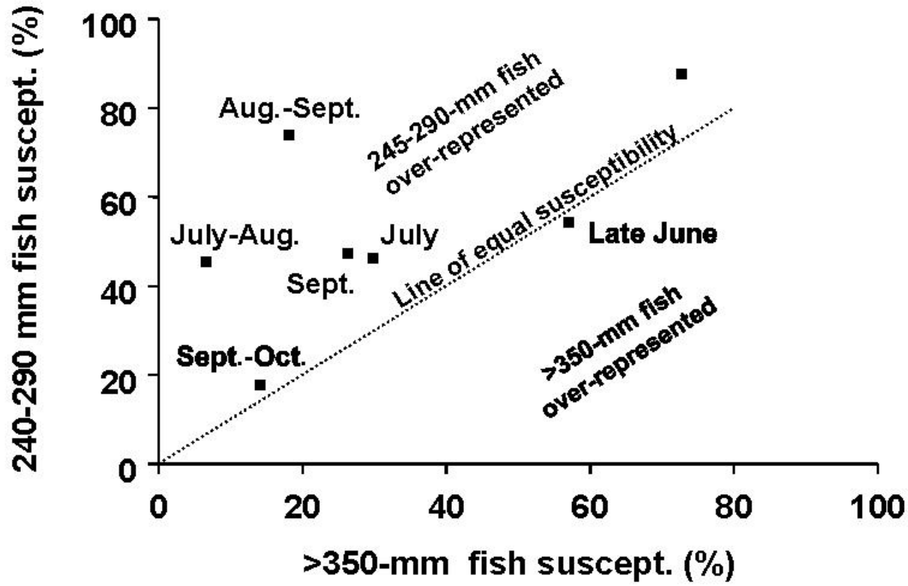

Figure 23. Plot of electrofishing susceptibility of medium (240-290 mm) vs. large (≥ 350 mm) smallmouth bass. Susceptibility was calculated for 20-d periods from mid-May through mid-October 1996. Smallmouth bass were considered susceptible to electrofishing if the bottom depth at their location was ≤ 2-m deep and the location was ≤ 10-m from shore.

When electrofishing susceptibility is similar between the two length groups studied, bias in indices of size structure should be minimized. Electrofishing susceptibility during the June-July sampling period was three times as high as during the September-October sampling period, meaning a larger sample would be obtainable if a standard electrofishing survey were scheduled for the June-July period, rather than for the September-October period. The objective of determining periods of the year when electrofishing susceptibility was similar for medium and large smallmouth bass was to establish a standard survey period during the year when bias in structural indices estimates would be minimized because similar electrofishing susceptibility existed.

Other authors have developed correction factors for electrofishing (Beamesderfer and Rieman 1988) and scuba (Cole 1994) data in attempts at reducing bias in structural indices calculated for smallmouth bass populations. Unfortunately, mark-recapture estimates of smallmouth bass abundance for larger fish are difficult to generate because recapture rates of larger marked fish are usually quite low (Beamesderfer and Rieman 1988). Using electrofishing, gill netting, and angling as capture methods, a significant negative correlation was documented between recapture rate of tagged smallmouth bass and smallmouth bass length in John Day Reservoir, Oregon (Beamesderfer and Rieman 1988). This correlation was then used to correct PSD values and estimates of population size and annual mortality rates. The estimate of smallmouth bass population size only changed by 2% when corrected for size selectivity of pooled capture methods. However estimates for PSD and annual mortality increased by 20% and 22%, respectively. Smallmouth bass between 451 and 500-mm in length were one-third as vulnerable to recapture as were bass between 201-250-mm in length.

Cole (1994) compared depth use by three length groups of smallmouth bass with size structure estimates generated from scuba surveys on Green Lake. Maine. He determined that significant bias in RSD values occurred if scuba surveys were conducted after adults had completed the spawning and nest guarding period of the year and recommended that scuba surveys be conducted when water temperatures were 15-20^{o}C. In my study of smallmouth bass in Lake Oahe, South Dakota, 15 ^{o}C was also identified as the beginning of the spawning period. Electrofishing surveys should be initiated when water temperatures reach 15 ^{o}C and conclude when water temperatures reach 20^{o}C for Missouri River reservoirs. As a final consideration, electrofishing should not be conducted immediately after periods of high wind and onshore wave action, as such environmental conditions may reduce susceptibility of smallmouth bass to electrofishing (Teleki et. al 1977; Milewski and Willis 1990; this study). In this way, biases in estimates of population size structure can be minimized and the largest sample size obtained.

Conclusions and Management Implications

A standard June, nighttime electrofishing survey should be conducted on Missouri River reservoirs, when surface water temperatures are between 15^{o}C and 20^{o}C to monitor smallmouth bass population structure and dynamics. Electrofishing should only be considered a part of the smallmouth bass fishery assessment sampling methodology. Angler use and harvest and tagged fish reporting information should also be routinely gathered and incorporated into assessments of fishery status.

Information on smallmouth bass habitat use and movement in lower Lake Oahe has been gathered and summarized and will be made available to anglers for the purpose of increasing hourly catch rates of large smallmouth bass by anglers. However, increasing angler knowledge of large smallmouth bass habitat use may potentially result in an increase in harvest of large fish and a decrease in the quality (size structure) of the smallmouth bass population. During the spawning-and-rearing and fall-over-winter seasons, large smallmouth bass are more vulnerable than during other periods of the year due to proximity to shore (spawning and rearing) and high concentrations of fish in small areas (fall-over-winter). Any attempts at increasing use of the smallmouth bass population on Lake Oahe should be matched by efforts at educating anglers of the importance of routinely releasing smallmouth bass > 350-mm in length to ensure the continued quality of the fishery.

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Appendix

Appendix 1. Tracking history of smallmouth bass implanted with ultrasonic transmitters in lower Lake Oahe, South Dakota during 1996 and 1997.

Transmitter code	Dangler tag number	Implantation date	Capture location	Fish size	Physical characteristics			Tracking period dates		Notes
					Length (mm)	Weight (g)	Sex	Beginning	Ending	
2244	1012	5/14/96	Oahe Dam	large	415	----		5/25/96	5/25/96	Tag recovered 6/17/96 – Peoria Flats
355	1014	5/14/96	Oahe Dam	large	366	----		5/25/96	8/27/96	
2343	1015	5/14/96	Oahe Dam	large	428	----		-----	-----	
364	1016	5/14/96	Oahe Dam	large	368	----		5/25/96	6/24/96	Tag recovered 7/29/96 – Spring Creek
274	1017	5/14/96	Oahe Dam	large	367	----		6/22/96	10/15/97	Caught & released 6/96 – Nystrom Bay
337	1013	5/15/96	Oahe Dam	large	360	728	F	5/25/96	6/18/96	Tag recovered 6/24/96 – West Shore
283	1018	5/15/96	Oahe Dam	large	392	981	F	6/26/96	9/30/97	
256	1019	5/15/96	Oahe Dam	large	383	870		5/31/96	6/19/97	Caught & released 7/12/96 – Peoria Flat
247	1020	5/15/96	Oahe Dam	large	390	890		5/25/96	5/15/97	
2235	1021	5/15/96	Oahe Dam	large	375	754	M	5/31/96	7/18/96	Harvested 7/18/96
2352	1022	5/15/96	Oahe Dam	large	395	856		6/10/96	7/18/96	Caught & released 6/20/96 and 7/7/96 at West Shore and Spillway
339	1034	6/5/96	Oahe Dam	medium	252	235	F	6/18/96	8/27/96	
357	1035	6/5/96	Oahe Dam	medium	278	351	M	6/10/96	9/5/97	Caught & released 6/8/96 – West Shore
348	1036	6/5/96	Oahe Dam	medium	256	254	F	6/10/96	6/28/96	Caught & released 6/15/96 – Oahe Dam
375	1037	6/5/96	Oahe Dam	medium	245	218	M	6/10/96	6/28/96	
2246	1038	6/5/96	Oahe Dam	medium	261	246	M	6/10/96	6/19/97	
276	1039	6/5/96	Oahe Dam	medium	251	238	M	7/25/96	7/25/96	
88	1040	6/5/96	Oahe Dam	medium	254	261	M	6/10/96	8/5/97	Caught and released twice on 8/25/96
555	1041	6/5/96	Oahe Dam	medium	264	270	F	6/14/96	7/3/96	Tag recovered 7/29/96 – Spring Creek
366	1042	6/5/96	Oahe Dam	medium	254	224	F	6/10/96	7/3/96	Caught & released 6/15/96 – West Shore
267	1043	6/5/96	Oahe Dam	medium	278	359	M	6/10/96	9/12/96	Harvested 9/13/96 – Oahe Dam
2237	1044	6/5/96	Oahe Dam	medium	276	289	F	6/10/96	7/18/96	

Appendix 1 continued…

Transmitter code	Dangler tag number	Implantation date	Capture location	Fish size	Physical characteristics Length (mm)	Weight (g)	Sex	Tracking period dates Beginning	Ending	Notes
229	1001	5/8/96	Spring Cr.	large	424	1215	F	5/28/96	6/22/96	Tag recovered 7/1/96 – Spring Creek
445	1002	5/8/96	Spring Cr.	large	361	759	M	6/11/96	10/15/97	
346	1003	5/8/96	Spring Cr.	large	362	745	M	5/28/96	6/26/96	Expelled by 7/20/96 – Sully Flats
3333	1004	5/8/96	Spring Cr.	large	405	1086	F	5/28/96	6/13/96	
2325	1005	5/8/96	Spring Cr.	large	371	710	M	5/28/96	9/30/97	
238	1006	5/13/96	Spring Cr.	large	392	694	F	5/28/96	5/28/96	
265	1007	5/13/96	Spring Cr.	large	366	770	----	6/11/96	6/25/97	Tag recovered 7/29/96 – Spring Creek
2424	1008	5/13/96	Spring Cr.	large	370	651	F	6/14/96	6/13/96	
2226	1009	5/13/96	Spring Cr.	large	384	820	F	5/28/96	7/25/97	
2253	1010	5/13/96	Spring Cr.	large	364	695	F	5/28/96	6/11/96	Tag recovered 7/29/96 – Spring Creek
2334	1011	5/13/96	Spring Cr.	large	361	690	F	5/28/96	6/11/96	Caught by angler 6/14/96 Tag recovered 7/29/96 – Spring Creek
258	1023	6/3/96	Spring Cr.	medium	276		F	6/11/96	5/15/97	
97	1024	6/3/96	Spring Cr.	medium	253		M	6/13/96	6/22/96	Tag recovered 7/29/96 – Spring Creek
384	1025	6/3/96	Spring Cr.	medium	277		M	6/4/96	7/1/96	Harvested by spear-fisherman
249	1026	6/3/96	Spring Cr.	medium	256		F	6/13/96	6/13/96	Tag recovered 7/13/96 – Cow Creek
447	1027	6/3/96	Spring Cr.	medium	257		F	6/11/96	7/22/96	
456	1028	6/3/96	Spring Cr.	medium	274		F	6/11/96	6/11/96	Tag recovered 7/13/96 – Spring Creek
2255	1029	6/3/96	Spring Cr.	medium	284		F	-----	-----	
2228	1030	6/3/96	Spring Cr.	medium	289		M	6/11/96	7/12/96	
465	1031	6/3/96	Spring Cr.	medium	278		F	6/11/96	8/7/97	
285	1032	6/3/96	Spring Cr.	medium	257		F	6/11/96	6/22/96	
294	1033	6/3/96	Spring Cr.	medium	265		M	6/14/96	8/14/96	

Appendix 1 continued…

Transmitter code	Dangler tag number	Implantation date	Capture location	Fish size	Physical characteristics			Tracking period dates		Notes
					Length (mm)	Weight (g)	Sex	Beginning	Ending	
2244*	1045	6/26/96	Oahe Dam	large	376	705	F	6/28/96	10/16/97	
337*	1046	6/26/96	Oahe Dam	large	366	730	F	6/28/96	6/19/97	
229*	1047	7/2/96	Spring Cr.	large	375	775	M	7/8/96	8/26/96	
456*	1048	7/13/96	Spring Cr.	medium	258	215	----	7/22/96	9/10/96	
384*	1050	7/13/96	Spring Cr.	medium	257	204	M	7/22/96	8/19/96	
249*	1049	7/13/96	Spring Cr.	medium	263	261	F	7/22/96	7/25/97	
447*	1052	8/9/96	Oahe Dam	medium	253	----	M	8/12/96	10/16/97	Caught & released 9/12/96
555*	1053	8/9/96	Oahe Dam	medium	253	----	----	8/12/96	5/9/97	
97*	1054	8/9/96	Oahe Dam	medium	246	----	----	8/12/96	9/28/96	
2334*	1051	8/9/96	Oahe Dam	large	413	----	----	8/12/96	10/7/96	Caught & released 9/10/96
294*	1055	8/24/96	Spring Cr.	medium	276	----	----	8/26/96	10/22/96	
384*	1056	8/24/96	Spring Cr.	medium	251	----	----	8/26/96	10/9/96	
346*	1057	8/25/96	Spring Cr.	large	341	----	----	-----	-----	
267*	1058	9/30/96	Oahe Dam	medium	265	----	----	10/28/96	6/13/97	
364*	1059	5/14/97	Spring Cr.	large	421	1128	F	5/15/97	10/15/97	
2235*	1061	5/14/97	Spring Cr.	large	424	1121	F	5/15/97	5/15/97	
2253*	1060	5/14/97	Spring Cr.	large	396	774	M	5/15/97	10/15/97	

* denotes re-implantation of transmitters in new fish after recovery.

Appendix 2. Spearman's Rho correlation coefficients for correlations between characteristics of medium (240-290 mm) and large (≥350 mm) smallmouth bass habitat use or movement and environmental variables, for lower Lake Oahe, South Dakota, May-October 1996. *P* is the probability level if *P* values were <0.05, NS (not significant) represents *P* values >0.05, r_s is the correlation coefficient and n is sample size.

Variables	**Fish size**	**Month (s)**	**n**	**r_s**	***P***
Depth and distance to shore	Medium	May	--	-----	--
	Large		27	0.164	NS
	Combined		--	----	--
	Medium	June	134	0.301	<0.001
	Large		97	0.582	<0.001
	Combined		237	0.449	<0.001
	Medium	July	131	0.401	<0.001
	Large		77	0.816	<0.001
	Combined		208	0.622	<0.001
	Medium	August	185	0.376	<0.001
	Large		131	0.659	<0.001
	Combined		316	0.618	<0.001
	Medium	September	141	0.765	<0.001
	Large		141	0.652	<0.001
	Combined				
	Medium	October	49	0.821	<0.001
	Large		57	0.703	<0.001
	Combined		106	0.762	<0.001
Bottom depth occupied and occupied temperature	Medium	May	--	----	--
	Large		29	-0.226	NS
	Combined		--	----	--
	Medium	June	153	-0.019	NS
	Large		98	-0.077	NS
	Combined		251	0.042	NS
	Medium	July	136	-0.408	<0.001
	Large		82	-0.381	<0.001
	Combined		218	-0.393	<0.001
	Medium	August	190	-0.389	<0.001
	Large		139	-0.234	<0.005
	Combined		329	-0.351	<0.001
	Medium	September	151	-0.351	<0.001
	Large		156	-0.178	<0.025
	Combined				
	Medium	October	60	-0.198	NS
	Large		60	0.120	NS
	Combined		120	-0.063	NS

Appendix 2 continued…

Variables	Fish size	Month (s)	n	r_s	*P*
Bottom depth occupied and occupied temperature	Medium	May-October	690	-0.234	<0.001
	Large		564	-0.097	<0.025
	Combined		1254	-0.180	<0.001
Distance to shore and occupied temperature	Medium	May	--	----	--
	Large		27	0.107	NS
	Combined		--	----	--
	Medium	June	153	0.015	NS
	Large		97	0.043	NS
	Combined		250	0.013	NS
	Medium	July	136	-0.166	<0.05
	Large		82	-0.304	<0.005
	Combined		218	-0.225	<0.01
	Medium	August	190	-0.227	<0.001
	Large		139	-0.287	<0.001
	Combined		329	-0.172	<0.001
	Medium	September	151	-0.270	<0.001
	Large		156	0.152	<0.05
	Combined				
	Medium	October	58	-0.402	<0.005
	Large		58	-0.119	NS
	Combined		116	-0.269	<0.005
	Medium	May-October	688	-0.124	<0.001
	Large		559	0.110	<0.005
	Combined		1247	-0.025	NS
Surface light intensity and distance to shore	Medium	May	--	----	--
	Large		27	-0.029	NS
	Medium	June	133	0.159	<0.05
	Large		97	0.039	NS
	Medium	July	118	0.062	NS
	Large		74	-0.060	NS
	Medium	August	184	0.141	<0.05
	Large		131	0.052	NS
	Medium	September	139	0.048	NS
	Large		139	0.211	<0.025

Appendix 2 continued…

Variables	Fish size	Month (s)	n	r_s	***P***
Surface light intensity and distance to shore	Medium	October	47	-0.062	NS
	Large		56	0.014	NS
	Combined		103	0.030	NS
Surface light intensity and bottom depth	Medium	May			
	Large		27	0.323	0.05
	Combined				
	Medium	June	133	0.302	<0.001
	Large		96	0.173	<0.005
	Combined		233	0.273	<0.001
	Medium	July	118	-0.004	NS
	Large		74	-0.080	NS
	Combined		192	-0.007	NS
	Medium	August	184	0.16	<0.025
	Large		131	0.142	0.05
	Combined		315	0.134	<0.001
	Medium	September	139	0.144	<0.05
	Large		139	0.079	NS
	Combined		278	0.108	NS
	Medium	October	47	-0.154	NS
	Large		56	0.145	NS
	Combined		103	0.010	NS
Movement per hour and barometric pressure	Medium	May			
	Large		12	-0.166	NS
	Combined				
	Medium	June	87	-0.319	<0.005
	Large		48	0.017	NS
	Combined		135	-0.148	<0.005
	Medium	July	86	-0.037	NS
	Large		38	0.201	NS
	Combined		124	0.067	NS
	Medium	August	135	-0.037	NS
	Large		87	-0.158	NS
	Combined		222	-0.095	NS
	Medium	September	99	-0.098	NS
	Large		90	-0.108	NS
	Combined		189	-0.092	NS
	Medium	October	18	0.001	NS
	Large		23	0.043	NS
	Combined		41	0.085	NS